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HOUSING IN NORTHERN CANADA: SOME RECENT DEVELOPMENTS

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[*MS. received 11 April 1960.*]

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Introduction

The northern part of Canada is probably the most isolated, sparsely populated, and inaccessible land mass in the northern hemisphere. The Yukon and Northwest Territories comprise an area of 1½ million sq. miles and contain only 34,000 people, 8,300 of whom are Eskimo. Into this vast area only one navigable river penetrates, and the sea lanes around its perimeter are open for only three months in the year. This isolation and scarcity of people are reflected in the following comments of the Royal Commission on Canada's Economic Prospects: "In the whole of the Northwest Territories...the military bases, mining camps, trading posts and administrative centres are hardly more than pin-pricks in the surrounding bush and muskeg and barrens. There will be important economic development in this area in the years to come. But it would take the ruthlessness of a Peter the Great to plant any large centres of population there."

Regardless of what the future may hold, the provision of adequate shelter in these regions will continue to be a matter of basic concern. Recent activity has already stimulated considerable interest in the development of building systems and techniques designed to satisfy the special requirements of northern housing.

Contrary to popular belief, these special northern requirements do not arise because of any basic differences in the kinds of technical problems that must be met, but are dictated instead by the peculiar economic and logistic factors of the north. The northern climate is not much more severe than other cold areas of Canada such as the Prairie Provinces. It differs mainly in the duration of cold weather rather than in the extremes of temperature. This leads to the widespread existence of permafrost and so affects foundation design, but climate alone does not call for special superstructure design.[1] Conventional, insulated wood-frame construction such as has evolved in southern Canada performs satisfactorily in even severe northern exposures. Thus the search for alternative materials or building systems for the north arises not from the technical unsuitability of normal wood-frame construction but is dictated

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primarily by questions of cost; northern transport and site labour can increase conventional wood-frame house costs some two to five times over the cost of such construction in the south.

The problems of northern housing normally separate into two distinct parts: the provision of improved Eskimo housing, using self-help labour and indigenous materials where possible, with little economic pressure for minimizing site labour; and the building of new communities and civil or military bases with imported building systems, in which northern economics dictate light weight and rapid erection to reduce the very costly transportation and site labour elements.

Eskimo housing

The Department of Northern Affairs and National Resources, the Federal Government agency responsible for administration of the north of Canada, has undertaken the development of improved self-help housing for the Eskimo, and the Division of Building Research of the National Research Council has been privileged to assist with this project from time to time. The ingeniously developed shelters of the Eskimo were well suited to his earlier nomadic existence, but are not adequate for long-term occupation by settled groups, which now include the majority of these northern people. The snow igloo is at best a seasonal shelter remaining well insulated for only a few weeks; it becomes increasingly damp and cold with continued occupation and there are long cold periods in the autumn when snow is not available. Like the snow igloo, the Eskimo's tents of caribou skin and canvas and his more recent shelters of scavenged packing crates, oil drums, and cardboard are very small and damp. He cannot afford to heat large areas without improving the insulation, and often a family of three to five are accommodated in an area of only 100 sq.ft. (9 sq.m.). The very high incidence of respiratory diseases among the Eskimo has led to increasing concern about his housing, and the first developments aim at larger, better insulated and drier quarters, yet basically simple and at a cost he can afford.

The use of indigenous materials has been carefully explored as a means of meeting this cost requirement. Unfortunately, local materials are few and of limited value in constructing improved housing. Stone has poor thermal qualities. Sand and gravel require large quantities of cement before they can be made into a structural material. Timber is available only in the Mackenzie River valley in the Western Arctic and in sections of Ungava in the Eastern Arctic. There are, however, indigenous insulation materials suitable for self-help projects. Tests by the Division of Building Research have shown that caribou moss (*Cladonia* sp.) can provide insulation value almost equal to mineral wool, when dried and compressed to half its loose volume. In addition, peat sod can be used where available to build up thick walls.

Using these materials an improved Eskimo house has been developed with light rigid frames of 2 by 4 in. (5 by 10 cm.) timber supporting peat-sod exterior walls and an oiled and battened plywood roof. A plywood floor is supported on 2 by 4's directly on the ground in these huts, protected underneath with a sheet polyethylene ground cover and insulated with 4 in. (10 cm.)

of caribou moss. Walls and roof are insulated with 4 in. of caribou moss between the frames, and the interior of the hut is lined with sheet polyethylene which serves as a vapour barrier and wall finish. These owner-built sod huts, 12 by 20 ft. (4 by 6 m.), are very rudimentary, but offer marked improvement over the former primitive houses and are relatively inexpensive.

For areas where peat sod and caribou moss are not available, a light rigid framed plywood hut has been developed, in co-operation with the Plywood Manufacturers Association of British Columbia, to achieve low costs in northern-built housing with imported materials (see photograph facing p. 230). The hut uses stained plywood as roof, exterior and interior cladding, and floor, and weighs only about half as much as conventional frame huts using board sheathing and separate board siding. These huts are also supported directly on well-drained ground on a plastic ground cover. Within the floor, walls and roof, 4 in. (10 cm.) of mineral wool insulation is placed and again this is fully protected on the inside with sheet plastic vapour barriers. The cost of materials for the sod and plywood huts is $200 and $400 respectively.

Recent housing developments

Prefabrication. In the building of northern communities for military, commercial, and administrative groups, the high transportation and labour costs and the very short construction season favour full prefabrication to achieve minimum weight and erection time. Transport costs of over $100 per ton by boat and 50 c. to $1.00 per lb. by air are common, and the boat trip takes a month or more out of the already short working season of about four months. As already mentioned, these factors cause heavy wood-frame houses to cost two to five times as much in the north as do their southern counterparts. With these over-riding incentives of economics and logistics, most advances in northern housing over the past decade have been in the field of light-weight prefabrication. Prefabricated units have been developed which weigh less than half that of conventional site-built wood-frame construction and which can be erected in one-tenth the time. With good advance planning and organization on large projects, these light-weight systems allow very much reduced northern building costs.

As in southern Canada, prefabrication in the north varies from precut wood and metal systems to engineered light-weight panel systems. Northern prefabrication has, however, far outstripped southern progress. In the south, only the simple wood-frame systems have achieved any measure of use, and prefabrication in total accounts for only 2 to 3 per cent of house construction (compared to over 10 per cent in the United States). In the north the more advanced systems have largely displaced the heavier frame "prefabs", and a large share of all recent northern housing is prefabricated.

Precut systems. It is questionable whether precutting should be classed as even a degree of prefabrication, but precutting pieces to exact size in the shop is a first means of reducing on-site labour requirements, and because of this some precut systems have seen extensive northern use.

Precut log units have been popular in the "near north". These were adapted from Scandinavian practice by Canadian manufacturers, using 4-in. (10 cm.) cedar logs machined to a tongue-and-groove mating detail to form the walls, and using conventional precut floor and roof systems. These generally sound and attractive units are prohibitively heavy for "far northern" use, and the logs do not provide sufficient insulation for the high fuel cost areas of the north in comparison to insulated frame construction. Although low in first cost, their cost in place in the north is well above light-weight panel units. Weights, erection times, and cost estimates for these and other prefabricated systems discussed here are compared in the following table.

Type	Package cost in $	Transportation: Weight in tons	Transportation: Cost in $	Labour and overhead: Time in hr.	Labour and overhead: Cost in $	Contingencies: 30 per cent of Transport + Labour in $	Total in $
Wood-frame panel	4,600	21	3,150	120	720	1,160	9,730
Precut log	4,500	23	3,450	150	900	1,300	10,150
Typical stressed skin panel	4,900	12	1,800	60	360	650	7,750
Typical sandwich panel	9,800	10	1,500	40	240	520	12,060
Comparative site-built wood-frame house	3,600	21	3,150	700	4,200	2,200	13,150

Comparative costs of prefabricated systems in Northern Canada

These cost estimates are for finished, but unserviced, buildings of 24 by 48 ft. (7·3 by 14·6 m.) in plan, assumed to be erected on gravel pads at Frobisher, Northwest Territories.

The various metal clad, metal framed buildings are essentially precut shell systems. On the basis of first cost these metal structures appear to offer advantages over wood-frame construction, but for northern use they require the laborious fitting of insulation and application of cladding to the metal shell. This often amounts to the equivalent of building a wood-frame structure inside the shell, an operation that involves much site labour and leads to high final costs. Because of the difficulty of providing unbroken vapour barriers, extensive condensation difficulties have plagued these buildings in northern use. Although formerly used to a large extent for military operations, they cannot be considered a good prefabricated system for heated northern housing. These comments do not necessarily apply to the fully prefabricated and insulated metal skinned panel systems.

Wood-frame panel systems. Panel prefabrication has received the widest consideration for northern use. The first northern applications in the early 1940s consisted simply of conventional frame wall construction in panel form. Since the floor and roof are usually only precut, sometimes with trussed rafters, the erection time for these units is only fair and their weight is very high in comparison with the new systems. As shown in the table their cost position in the north is not favourable. In the late 1940s, wood-frame prefabs began competing with, and are now largely supplanted by, stressed skin units.

Stressed skin panel systems. The search for light-weight structures led to the development of "stressed skin" systems in the early 1930s, beginning with the stressed skin housing study of the United States Forest Products Laboratories. Stressed skin design utilizes light, strong, sheet materials as structural "skins" (usually plywoods), which are bonded to stabilizing wood webs to form an enclosed panel. These panels can act efficiently in either edge compression or in bending, and when insulated and coated they serve as complete structural wall panels as well as floor and roof panels for relatively long spans. They are usually 4 ft. wide and 8 to 12 ft. long (1·2 m. by 2·4 to 3·7 m.). They are normally insulated with mineral wool and are 3 to 4 in. thick (10 cm.) for northern use to provide sufficient thermal value[2] (Fig. 1). With appropriate jointing details they may quickly form finished buildings of one or two stories.

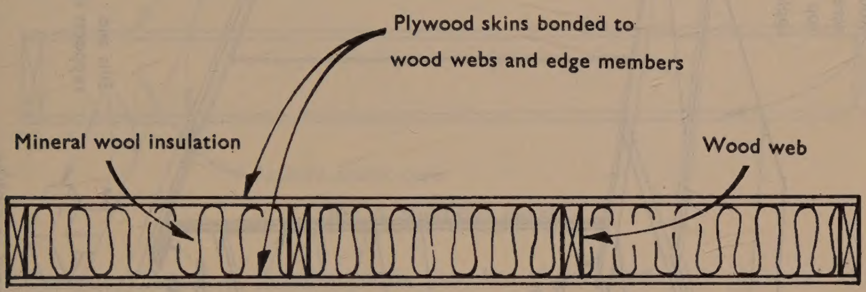


Fig. 1. Stressed skin panel.

Introduced throughout most of the north from 1945 to 1950, they have been used in nearly all northern projects to form military barracks, airport buildings, commercial and administration housing and offices, radar line buildings, schools, hospitals and whole towns. To date, these stressed skin units have best met the economic factors in northern housing and have also given satisfactory technical performance. A typical stressed skin assembly is shown in Fig. 2. These and other panel units are usually sited on gravel pads on the permafrost, or on wood piles which are steamed or drilled into the permafrost.

From the first, stressed skin panels have depended on the plastic resin adhesives (phenolics, resorcinols, or ureas) to provide long-term bonding. The development of these and other plastic adhesives, and the further development of light plastic core materials, has led to recent utilization of the stressed skin concept in the form of "sandwich panels".

Structural sandwich systems. The structural sandwich concept also uses light load-bearing skins (plywoods, hardboards, asbestos boards, or metals) in stressed skin action, but here full-size "cores" are used to stabilize the skins more efficiently and at the same time act as insulation (Fig. 3). These core materials are now usually paper-plastic "honeycombs", or foamed polystyrene or polyurethane plastics. Sandwich developments began with the famous British "Mosquito" bomber aircraft, and it was soon realized that the

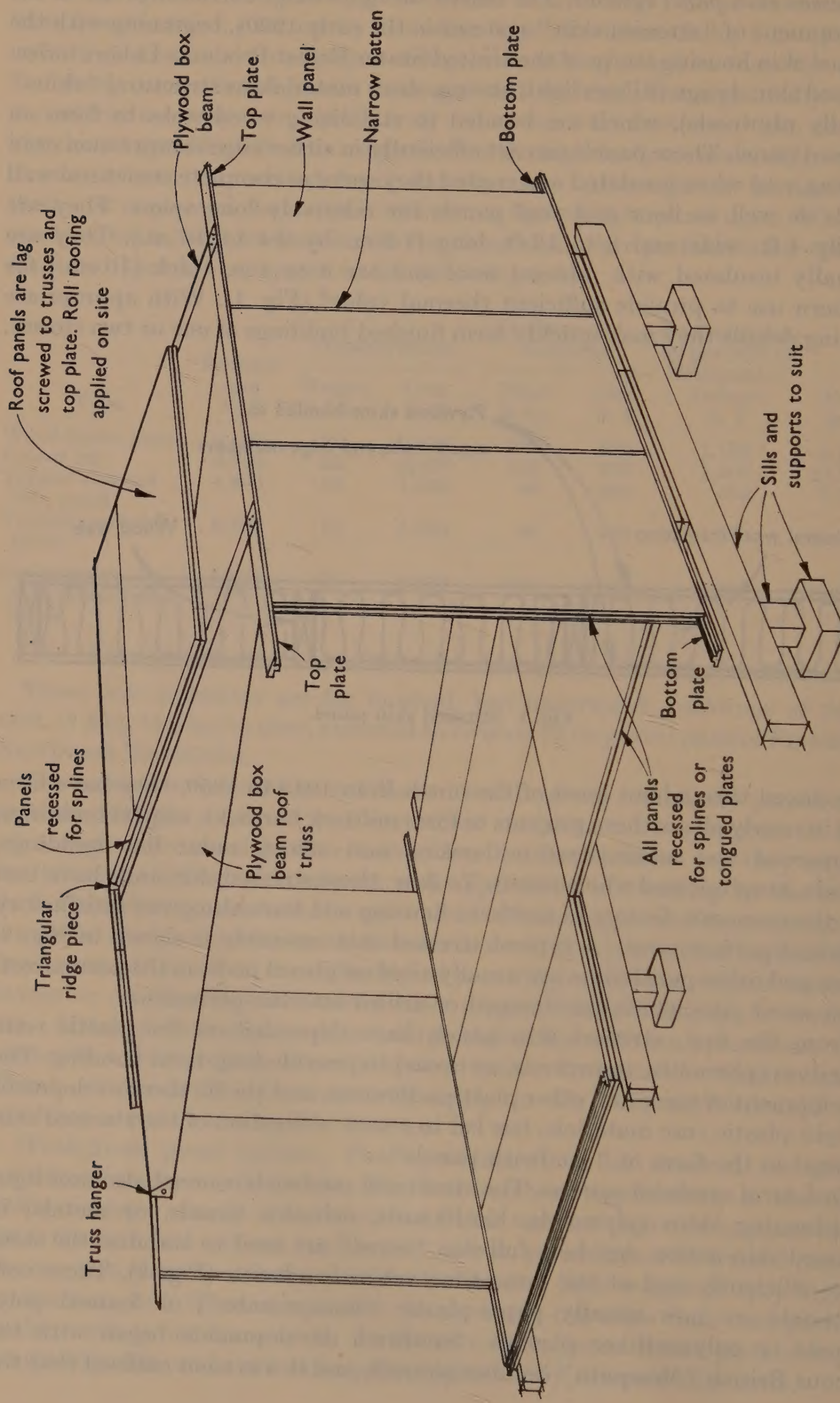


Fig. 2. Stressed skin panel assembly.

sandwich is the most efficient possible structural form for either bending or edge compression loading.

In 1950 the United States Navy erected the first sandwich units in the north, using structural floor, wall, and roof panels with thin aluminium skins bonded to paper-plastic honeycomb cores. The weight of these Arctic huts, 24 by 48 ft. (7 by 14·5 m.), would be under 6 tons (5,450 kg.), as against 10 tons (9,070 kg.) for the plywood skinned sandwich units now used in the north, 12 tons (1,090 kg.) for the plywood stressed skin units, and 21 tons (1,900 kg.) for conventional wood-frame units. Transportation savings are obvious.

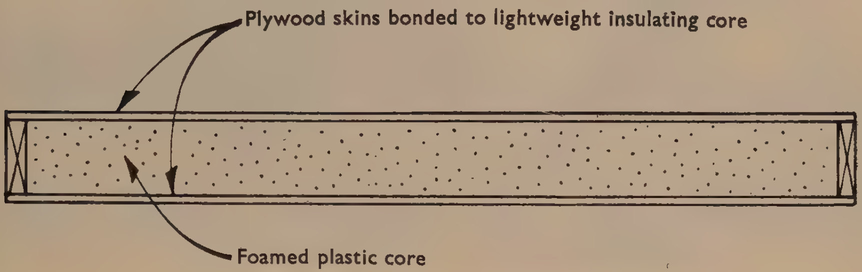


Fig. 3. Sandwich panel.

Current Canadian developments involve $\frac{5}{16}$ in. (0·8 cm.) plywood skins bonded to a 4-in. thick (10 cm.) foam polystyrene core for wall, roof, and floor panels with a special metal "cam-lock" panel connector. Such connexions permit fast panel erection using only an "Allen" wrench, about half the time required for stressed skin construction using bolted T and batten or splined connexions. A typical building is shown in the photograph facing p. 230. Although these panels achieve very efficient use of materials, their first cost has remained high, about twice that of stressed skin units.

As shown in the table (see p. 226), the somewhat reduced weight and erection time of these technically sound sandwich units do not offset their initial high cost in northern use. United States manufacturers claim that with new manufacturing processes these types of sandwiches are now competitive in first cost with wood-frame or stressed-skin systems. If volume production proves this in Canada, the light sandwich systems should assume a larger share of the northern market.

Conclusion

Although cost is a major determining factor in the selection of northern buildings, and has been a prime concern in this discussion, it is also essential that each building system used in the north be technically adequate for cold weather conditions. The system must provide, in addition to strength and rigidity, resistance to heat flow, water vapour flow, liquid water movement, and fire. The prefabricated panels can individually meet these requirements, but the final performance of the structure is dependent on satisfactory joint

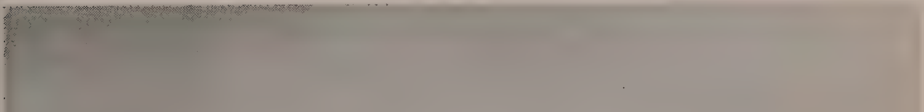
details, and these have often proved difficult. In recognition of the importance of total prefabrication in meeting the problem of northern building, the Division of Building Research has recently completed detailed studies of the currently available systems, the results of which will shortly be published in a technical paper. It is evident that the light-weight systems can meet these performance requirements. In addition, their modular panel design makes them adaptable to any type of building with flexibility in layout, window placement and appearance, and the low final cost of the stressed skin units in particular makes these, and further evolving systems, attractive in the establishment of communities in the north of Canada.

References

[1] R. F. Legget *and* H. B. Dickens. Building in northern Canada. *National Research Council, Division of Building Research, Ottawa, NRC*, No. 5108, 1959, 48 p.

[2] R. E. Platts. Insulation in northern building. *National Research Council, Division of Building Research, Ottawa, NRC*, No. 5280, 1959, 17 p.

Rigid frame plyhood hut.



Plastic sandwich panel unit.

Some recent developments of housing in northern Canada.

Photographs by Division of Building Research, National Research Council

(*Facing p.* 230)

Bank erosion on Peel River, 20 miles north of Fort McPherson. The bank is permanently frozen except for a thin top layer containing the tree roots. During the summer the face of the bank thaws and slides into the river, leaving the layer of roots and vegetation overhanging.

White spruce south of Fort McPherson. These stands, though not as extensive as the photograph suggests, average about 70 ft in height, and contain trees of sawtimber quality.

Forest resources of Mackenzie River basin, Northwest Territories.

Photographs by Forestry Operations Division, Department of Northern Affairs and National Resources

FOREST RESOURCES OF THE MACKENZIE RIVER BASIN, NORTHWEST TERRITORIES

BY J. M. ROBINSON[1]

[*MS. received 29 March 1960.*]

The Mackenzie River is the seventh longest river in the world and with its tributaries drains a million sq. miles of northern Canada. Its drainage basin includes almost all of that portion of the District of Mackenzie lying south of the so-called "tree line", two large sections of Yukon Territory and portions of the provinces of Saskatchewan, Alberta, and British Columbia. When flying from Fort Smith, lat. 60° N., to Inuvik near the Arctic Ocean it seems to be an endless expanse of swamp and tundra with almost no possibilities for logging, either now or in the future. Closer inspection, however, shows that there are forested areas capable of supplying timbers suitable for lumber and heavy construction, as well as poles for piling and mining timbers. It is with these forests that this article is primarily concerned.

On the west of the drainage basin, and stretching from the lat. 60° N. almost to the Mackenzie River delta, lie the very rugged Selwyn and Mackenzie Mountains; north and west of these the Richardson Mountains run parallel to the course of the Peel River and the Mackenzie River delta to the Arctic Ocean. East of the Mackenzie River lie the low Franklin Mountains which seldom exceed 3,000 ft. in altitude. These mountains, which terminate in the mesa-like Horn Plateau, are broken by the Great Bear River and several minor streams. South of the Mackenzie River and between the Liard and Hay Rivers lie the Cameron Hills. These mountains are primarily sedimentary, and the sedimentary region extends from the western boundary to the general line of Great Bear Lake, Hottah Lake, Faber Lake, the north-west arm of Great Slave Lake and the Slave River. To the east lie the igneous rocks of the Canadian Shield.

Across the barrens of both the sedimentary and igneous regions are found many eskers and moraines, but in general soils capable of sustaining tree growth are found only in the river valleys and on the lower slopes of the mountains. Flat sedimentary areas, such as are found east of the Franklin Mountains, consist of shallow lakes surrounded by open tundra. The Canadian Shield was very heavily glaciated and is distinguished by low, rounded, barren hills with lakes or peaty swamps between.

Although patches of larger trees may be found along the junction of the sedimentary and igneous rocks between Great Bear and Great Slave Lakes, along the eastern side of the Franklin Mountains, at the headwaters of the Taltson River, and in many other locations, almost all commercial timber

[1] Forest Management Section, Forestry Branch, Department of Northern Affairs and National Resources, Ottawa, Canada.

Fig. 1. Forest resources of the Mackenzie River basin.

suitable for sawtimber, pit props and piling is to be found in the valleys of the Mackenzie River and its major tributaries. Except for the lower slopes along the Liard River and occasional small patches in other sections, trees of sawtimber quality are confined to the rich alluvial soils in the river bottoms, particularly those which are infrequently flooded.

One of the major factors affecting tree distribution and tree growth in northern Canada is permafrost or perennially frozen ground. This condition is found in all of the District of Mackenzie, except possibly a small area along the Liard River and a narrow belt near lat. 60° N. The depth to permafrost in midsummer varies according to the drainage qualities of the soil, the type of vegetation growing on it, and, of course, the altitude. Near Fort Simpson the active (permafrost-free) layer of soil averages about 4 ft., while it is only a few inches in depth at Inuvik. In general, permafrost lowers the soil temperature and inhibits tree growth, but in certain conditions it can be an asset. The annual precipitation is very low, being only 13 in. at Fort Smith, 12 in. at Fort Simpson, and 10 in. at Fort McPherson. This vast area would be a semi-desert were it not for the permafrost which reduces drainage and supplies moisture during the warm growing season. Light soils retain little moisture so the upper layers may be relatively frost-free even near the Arctic Ocean. On the other hand, poorly drained clays and silts readily accumulate an insulating blanket of moss which lowers soil temperature and greatly favours the development of permafrost.

Although the growth rate of trees is much reduced by low soil temperatures, there is evidence to indicate that white spruce of sawtimber quality can develop on a very thin layer of active soil, if the moss layer is absent. Opposite Fort McPherson, Northwest Territories, a stand of white spruce averaging 70 ft. in height was growing on a moss-free alluvial flat which had little more than 1 ft. of active soil at the end of July. One tree growing in 18 in. of active soil had reached a height of 85 ft. and a diameter of 23 in. in 170 years.

The number of tree species capable of withstanding the rigorous climate of the Northwest Territories is small. Only on rich sites do white spruce (*Picea glauca*), balsam poplar (*Populus balsamifera*) and to a very limited extent trembling aspen (*P. tremuloides*) reach sawtimber size, and of these only white spruce is being utilized at present. Trees growing on the poorer sites are somewhat more varied. Jack pine (*Pinus banksiana*) and trembling aspen are found either alone or mixed with white spruce on the drier sites, and black spruce (*Picea mariana*) and varieties of white birch (*Betula* spp.) grow on the wetter and more acid soils. Jack pine extends as far north as 45 miles below the mouth of the Great Bear River. Trembling aspen was observed by the writer at Norman Wells but not at Fort McPherson or more northerly points. White spruce, black spruce, balsam poplar and white birch are reliably reported from the Reindeer Depot about 30 miles north of Inuvik. Patches of potentially commercial forest are scattered throughout this vast area and smaller trees suitable for fuelwood, light construction, and possibly lagging for mining purposes can be found on moraines and eskers in many otherwise barren sections.

A more detailed description of the forested regions is given below.

The natural levees of the Slave River between Fort Smith and Great Slave Lake are sufficiently raised above the general level to afford both adequate moisture and aeration, and thus provide excellent sites for white spruce. The patches of white spruce sawtimber along the river have been exploited for many years, until now it is difficult for the small loggers to compete with larger operators farther south. However, there are younger stands which will be important in the future.

West of the Slave River, and almost to the mouth of the Liard River at Fort Simpson, is a large clay plain sloping gently to Great Slave Lake in the east and to the Mackenzie River farther west. South of Great Slave Lake the plain is broken by low ridges ringed with the old beach lines which also extend in parallel lines across the plains. South of the Mackenzie River the plains slope gently to two sharp escarpments and then finally back to the Cameron Hills near lat. 60° N.

Because of poor drainage the plains have large areas of swamp and barren. Some of this may have been caused by forest fires but the over-all result is a very large proportion of waste. Trees of sawtimber quality are to be found only along the various small rivers flowing through this belt and on the northern slopes of the Cameron Hills. Small timber suitable for polewood, and possibly pitprops, is located on the well-drained areas near the Mackenzie River and on the escarpment faces.

North of the Mackenzie River conditions are very similar, with some forest on the southern slopes of the Horn Plateau.

The large Liard River rises in the Yukon Territory, crosses northern British Columbia and enters the Northwest Territories through the gap between the Mackenzie Mountains and the Cameron Hills. Warm southern and western winds seem to have ameliorated the climate here and tree growth is exceptionally good. Even the lower slopes of the mountains bear trees of sawtimber size. Though some of the rich alluvial flats have been burnt, the area along the Liard River from lat. 60° N. to the mouth of the South Nahanni River is probably the most suitable region for timber growth in northern Canada.

Near the mouth of the Liard River at Fort Simpson the soils are lighter and covered with jack pine, aspen, and white and black spruce. A similar area is to be found on the eastern side of Camsell Bend. Owing to repeated fires these forests are relatively young and it is possible that some of the spruce might reach sawtimber size. Similar small timber may be found on the higher banks of the Mackenzie River, the lower slopes of the Franklin Mountains and the large flood plain at the mouth of the Great Bear River. Patches of trees suitable for sawtimber are to be found on the river islands, on the alluvial flats at the mouths of tributaries, and along such rivers as the North Nahanni, Keele, Ramparts and Arctic Red.

From the Ogilvie Mountains in the Yukon Territory the Peel River flows east and then due north to meet the Mackenzie River at the southern end of the Mackenzie River delta. Up in the Yukon Territory, quite inaccessible to Mackenzie District markets, small patches of sawtimber are to be found along

the Peel River; with the intensive oil exploration near by, this timber may have considerable local importance. Farther north the alluvial flats of the Peel River become more extensive, and from above Fort McPherson to the Mackenzie delta are forests about 70 ft. high growing on as little as 1 ft. of frost-free soil.

The Mackenzie River delta is an enormous area of lakes, swamps and river channels. Near the mouth of the Peel River the forest is continuous but this quickly changes into narrow bands along the river channels and lakes. The forest finally disappears about 40 miles north of Inuvik, in about lat. 68° 45′ N.

Forest surveys have been made along the Slave River from Fort Smith to Great Slave Lake, along the Liard River, and along the Mackenzie River as far downstream as Norman Wells. Area and volume estimates from these surveys are as follows:

		Estimated timber volumes	
	Area mapped in sq. miles	Thousands of feet board measure for trees 10″ DBH* and greater	Cords (of 85 cu.ft.) for trees 4″ DBH and greater—all species
Slave River	1,185	85,000 (spruce)	Not compiled
Liard River	4,027	2,757,000 (spruce) 2,427,000 (poplar)	11,274,000 (softwoods) 9,551,700 (hardwoods)
Mackenzie River (Fort Providence to Norman Wells)	4,500	206,000 (spruce)	Not compiled

* Diameter breast high, or 4 ft. 6 in.

Provisional forest maps, covering an area of 11,500 sq. miles, have been prepared from air photographs for a proposed survey of the lower Mackenzie River and its tributaries. Other areas of lesser importance will be covered as required.

In 1956, the population of the District of Mackenzie was only 12,492 persons, and except for the 5,343 Indians and Eskimos (1951 census) most of the people were living in such settlements as Fort Smith, Yellowknife and Aklavik. Consequently the normal demand for lumber and construction timber is low. In 1958, the fourteen permit holders in the District of Mackenzie cut only the following:

Lumber	894,068 board ft.
Round timber	328,585 lineal ft.
Fuelwood	7,814 cords

It is true that much more lumber was used. The townsite of Inuvik was prepared and several large schools and hospitals were built, but, as the small local sawmills were not equipped for the production of large quantities of high-grade lumber and construction timber, most of this had to be brought by barge from more southerly regions. As the mining industry develops and the population increases the demand for lumber will also increase and more efficient sawmills will be built, but the present spasmodic market does not justify such expenditure.

One might reasonably ask: What is the future of the forests in the far north? If the world demand for minerals greatly increases mining in this region, can the limited area suitable for growing sawtimber-quality trees supply this potential market? Where commercially feasible, mature and overmature forests in this region should be logged for southern markets rather than wasted through decadence and decay. However, the present surveys of the forest resources of the Mackenzie District portion of the Mackenzie River basin indicate that in the long run they should not be considered as a reservoir for world export, but rather as a local supply of timber which will assist in the exploitation of the mineral wealth of northern Canada. With such a policy, despite their restricted area and the rigorous conditions in which they grow, the forests of northern Canada should be ample for all foreseeable demands.

EXPERIMENTS IN THE USE OF EXPLOSIVES IN SEA ICE

A summary of experiments conducted during joint Canadian—United States Beaufort Sea and Bering Sea Expeditions, 1949–54

BY WALDO K. LYON[1]

[*MS. received 24 March 1960.*]

CONTENTS

Introduction

An icebreaker is beset. Motion is impossible because of lateral pressure and packing in the surrounding ice. During the long hours of patient waiting for the pressure to subside, discussion on board often turns to the use of explosives as a means to break the ship free.

During the voyage of H.M.S. *Investigator*, 1850–53, Dr Alexander Armstrong, the ship's surgeon, was critical of Cdr. Robert McClure for not making more attempts to break the ship free by the use of black powder, not only at Mercy Bay but at other situations during their hazardous exploration around Banks Island. Apparently explosives were successfully used on occasions, but at other times Armstrong felt that McClure missed the exact moment in the ice conditions to exploit explosives. One hundred years later, in August 1954, the icebreaker U.S.C.G.C. *Northwind* made the passage from the Beaufort Sea through McClure Strait to become beset in ice north-west of Richard Collinson Inlet. In her impatience to break free, explosives were tried unsuccessfully on a large floe lying across the bow—an impressive demonstration of the disparity in magnitude between man-made and natural forces in an ice floe. None the less, there are, perhaps, special situations wherein explosives can be useful to ship operations.

During the six-year period, 1949–54, the United States Pacific Fleet conducted a series of scientific expeditions by "Wind-class" icebreaker and submarine in the Bering, Chukchi and Beaufort Seas. The United States Navy Electronics Laboratory participated in these expeditions and was responsible for the scientific guidance within the fleet task unit. The principal objects of the expeditions were oceanographic, hydrographic and sonar surveys and the

[1] United States Navy Electronics Laboratory, San Diego, California.

study of the sea ice canopy[1] in relation to submarine and icebreaker operations. An additional continuing task was the conduct of experiments with explosives in sea ice, which included detonations both within and below the ice and charges of various configurations, chemical type and size. The experiments were carried out by the United States Navy Underwater Demolition Team assigned to each ship. A summary of the results may be of interest.

Blowing holes on the surface

During the expedition by the icebreaker U.S.S. *Burton Island* to the Bering Sea in the winter of 1949, tests were made on blowing holes in the ice by explosive charges placed on the surface of the ice. The thickness of the sea ice was about 4 ft. and it was covered with a hard snow crust, 6 to 8 in. thick; air temperature was between −5° and −9° F. (−21° and −23° C.). The use of 40 lb. shaped charges[2] usually produced results shown in Fig. 1. A 40 lb. ammonium nitrate cratering charge detonated on the ice surface also produced a similar fracture; the brash-filled hole was 10 to 12 ft. in diameter, and major cracks extended over an area 30 to 45 ft. across.

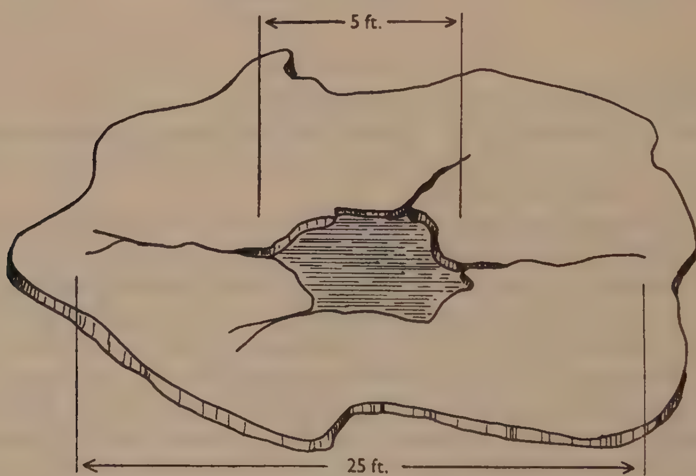


Fig. 1. Result from explosion of a 40 lb. shape charge.

A straight line, or bar, charge composed of two rows of 25 block charges each, was laid out on the surface of the floe. Each block charge in one row was 20 lb. of TNT, and in the other row 20 lb. of type C-3 plastic explosive. The total explosive weight of the bar charge was 1000 lb., and the over-all length was 30 ft. The charge blew a hole 30 to 50 yd. across, filled with brash ice with a central, nearly clear water, area 20 yd. in diameter. Four bar charges were then laid out on the ice, parallel to each other with 25 yd.

[1] The term "ice canopy" is used to connote the submariner's view of the sea ice cover above him and the protection it affords the submarine.

[2] A 40 lb. nominal shaped charge contains 30 lb. of explosive in a metal case, having stand-off legs to set the charge at proper distance from the surface to be penetrated by the explosion.

separation, as shown in Fig. 2*a*. Each bar charge consisted of one row of twenty-five 20 lb. charges of TNT. The resulting crater is shown in Fig. 2*b*. Again, instead of placing the charges in a line to form a bar charge, twenty-five 20 lb. charges of type C-3 plastic explosive were placed to form a circle 5 yd. in diameter. This circular charge blew a hole through the floe 30 to 50 ft. in diameter, filled with brash ice; the area of major cracks was 50 to 75 yd. across.

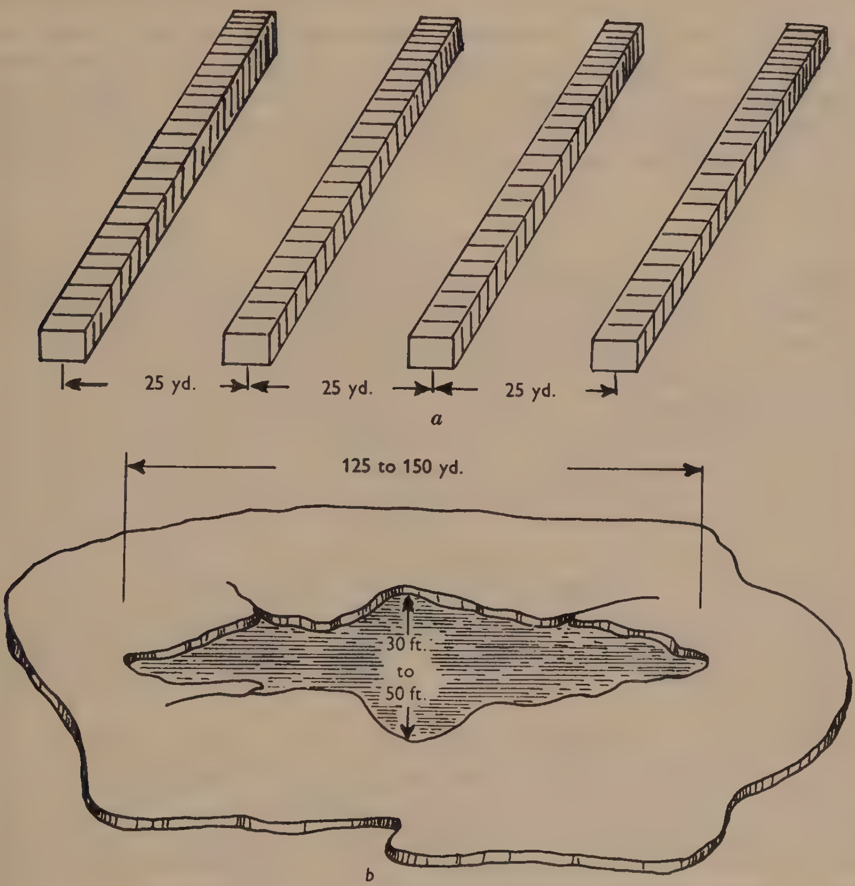


Fig. 2. Four 500 lb. bar charges: (*a*) placement; (*b*) result.

During the Bering Sea Expedition, in the winter of 1954, U.S.C.G.C. *Northwind* attempted to break a channel in a floe 4 ft. thick by using a distributed bar charge. The floe was approximately 700 yd. long by 500 yd. wide, and the air temperature was $-10°$ F. ($-23°$ C.). Two bar charges were laid out on the ice, each consisting of a line of separate charges spaced about 3 yd. apart. The total length of each line was about 220 yd. and the total amount of explosive in the two lines was 1400 lb. of TNT and C-3 plastic explosive. The resulting explosion did not create a channel, instead each charge blew a

separate hole through the ice which was not connected to its neighbours. Much smaller charges, properly buried, would have created greater effect.

In contrast, during the Bering Sea Expedition, in the spring of 1954, a channel was easily broken through a section of fast ice, 225 yd. wide, which was blocking the mouth of the Snake River at Nome, Alaska. The ice was 3 ft. thick and honeycombed from melt water and brine seepage. Air temperature was 30° F. (−1° C.), and a five knot current was flowing in the river. A series of 20 lb. TNT, or C-3 plastic explosive charges were placed in a line across the ice blockage, with about a 5 yd. interval between charges; each charge was buried in a hole 1 ft. deep and tamped in with ice and slush. The detonation produced a channel 20 to 30 yd. wide completely across the ice blockage, but filled with slush and chunks of ice. However, another channel 20 yd. wide, broke across the blockage some 80 yd. to one side of the detonated channel.

Effects of tamping

During the Joint Canadian–United States Beaufort Sea Expedition, 1953, a comparison was made of the explosive effectiveness of a charge tamped in with that of a similar charge fired on the surface of the ice. The test was carried out on a large ice floe, 15 to 18 ft. in thickness, during August 1953; the air temperature was 30·5° F. (−0·8° C.). One 40 lb. shaped charge was placed in a hand-made hole in the ice, 2 ft. in diameter and 2 ft. deep, filled with water to at least a depth of 6 in. over the shaped charge. The 6 in. water cover constituted the tamp-in. The second, similar shaped, charge was placed on the undisturbed surface of the floe. The resultant explosion of the buried charge produced a crater 10 ft. deep, and with a diameter of 8 ft. at the top and a small aperture at the bottom, in contrast to a shallow crater, 3 ft. in diameter to a depth of 1 ft., produced by the explosion of the charge lying on the ice surface. However, from the bottom of the shallow crater a hole extended to a depth of about 12 ft., which was 6 in. in diameter at the top and tapering to zero at the bottom.

A similar surface explosion made with a 15 lb. shaped charge ($11\frac{1}{4}$ lb. explosive) produced a hole 8 ft. deep, tapering from a diameter of 5 in. at the top to 2 in. at the bottom.

A test during the Bering Sea Expedition, in the spring of 1954, also illustrates the effect of tamping the charge. It was conducted on a large, flat ice floe $2\frac{1}{2}$ ft. thick, in an air temperature of 40° F. (4° C.). A 40 lb. shaped charge was set up above the ice using the standard standoff legs. Its detonation produced a hole 3 ft. in diameter through to the water. For comparison, a 15 lb. shaped charge without standoff legs was buried in a hole 1 ft. deep and detonated. The explosion produced a hole 6 ft. in diameter completely through the floe.

During the Bering Sea Expedition, in the winter of 1954, 80 separate detonations were made in sea ice, using $2\frac{1}{2}$ lb. TNT blocks, for the purpose of studying the propagation of elastic waves in sea ice. From the observation of these detonations and previous experience with shaped charges, both buried

and on the surface of the ice, it was agreed that bore holes can be made in an ice floe most readily and cheaply by burying a 2 to 5 lb. TNT, or C-3 plastic explosive charge in a small hand-dug hole. The large, shaped charges are not necessary and tend to scatter ice fragments over a wide area. A $2\frac{1}{2}$ lb. charge, properly buried, is sufficient to blast through 6 ft. of winter sea ice, creating a hole 3 to 5 ft. in diameter. For thicker sections, the charge size and depth of burial should be increased appropriately.

Detonation under ice

The much greater effect produced by an explosion under the ice, as compared to one on the surface, was observed by a simple test during the Bering Sea Expedition in the winter of 1951. The test was made on a flat floe, 39 in. thick with a 4 in. thick snow cover on top. A hole, 3 ft. in diameter, was made through the ice by using a 40 lb. shaped charge. Then 100 lb. of C-3 plastic explosive fastened to air-filled bladders was pushed down through the hole and back under the ice to a distance of about 20 ft. The air bladders gave the assembly slight positive buoyancy. The explosion produced a hole 50 ft. in diameter; no broken ice was found outside a radius of 100 ft.

The test was repeated using a hole drilled through the ice with a 3 in. diameter ice auger. A charge of 100 lb. of TNT, in the form of a string of $2\frac{1}{2}$ lb. blocks, was pushed down through the hole. Flotation bladders were attached to the string at intervals. The TNT blocks probably hung down at various distances beneath the ice. The explosion threw ice 200 ft. into the air, scattered pieces over an area 75 yd. in radius, and produced a hole 40 ft. in diameter filled with brash.

Another test was made to observe the effect of an under-ice explosion during the Joint Canadian–U.S. Beaufort Sea Expedition of 1953. A charge of 160 lb. of TNT assembled with flotation bladders was pushed under a large floe, 30 ft. thick. The air temperature was 30° F. (−1° C.), and the depth of water 50 ft., leaving 15 to 20 ft. of water beneath the ice and the sea bottom. There were insufficient flotation bladders to assure positive buoyancy, therefore the depth of the explosion is uncertain within the limits of the shallow water. An opening, 8 ft. in diameter, was blown in the floe. A charge of 460 lb. of TNT was then exploded on the surface of the floe with negligible effect on the ice other than scattering chunks of ice and disrupting surface configurations.

Use of explosives to assist ships in ice

During the winter of 1951, *Burton Island* was caught fast in ice while attempting to break through a pressure ridge in the Bering Sea. Demolition charges were used to free her. The ship was caught in a floe of flat ice 4 ft. thick with a pressure ridge running across it, estimated to be 20 ft. thick (Fig. 3). The icebreaker had a 3° list to port. Neither heeling, trimming nor backing at full power had any effect. The air temperature was −3° F. (−20° C.) with a 26-knot wind blowing 60° on the port bow. The first attempt to free the ship was made using 160 lb. of explosives, with 80 lb. placed on either side

of the bow, as shown in Fig. 3 (Trial 1). The explosion threw a considerable amount of ice into the air, about four times as much as that thrown by the later and bigger charge which freed the ship, probably because the charges were not buried deeply in the ice. Ice blown into the air should be kept to a minimum to avoid damage to the ship's superstructure and topside equipment.

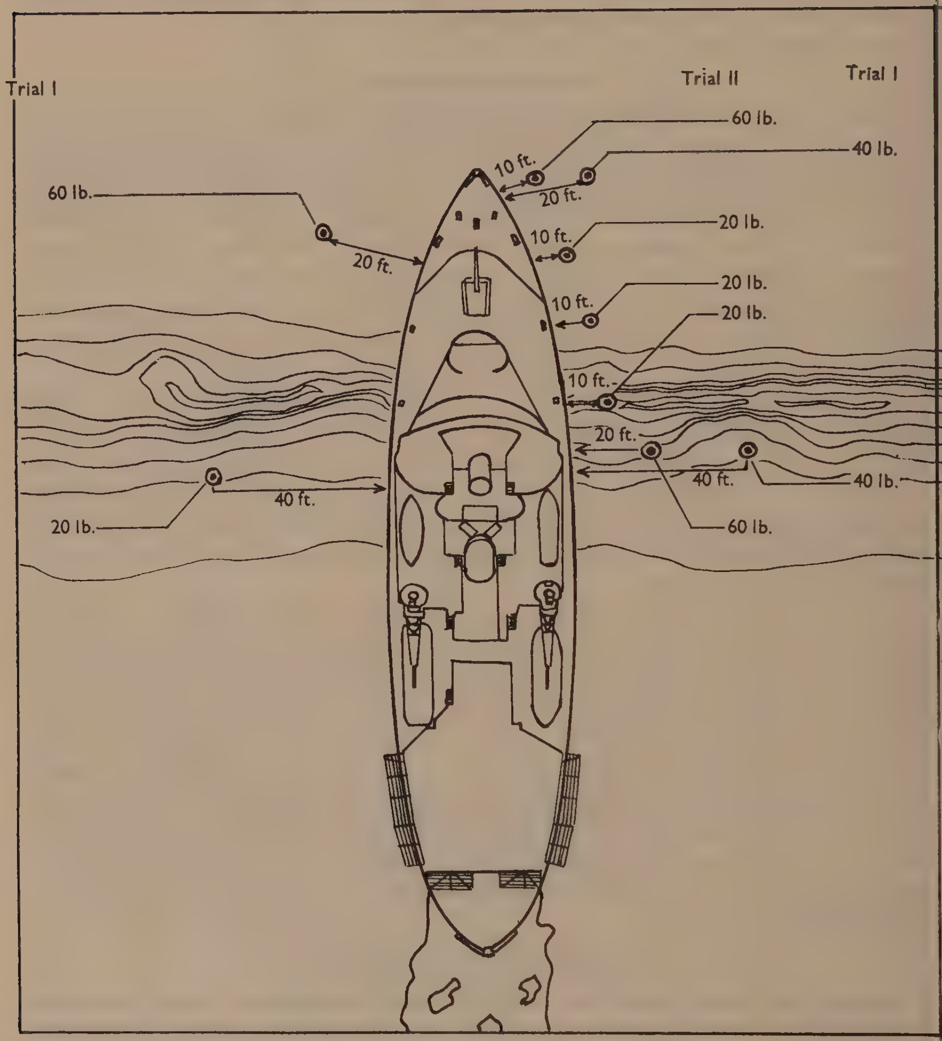


Fig. 3. Placement of charges to free a ship from a pressure ridge: Trial 1, 160 lb. total charge, unsuccessful. Trial 2, 180 lb. total charge, successful.

The placing and size of charges in the second attempt is shown in Fig. 3 (Trial II). The 60 lb. TNT charge at the bow was 10 ft. from the hull and sunk 3 ft. deep in the ice. The furthest aft charge, also 60 lb. TNT, was 20 ft. from

the side of the ship and 12 ft. below the surface of the ice. The three intermediate charges were 20 lb. each, placed 10 ft. from the hull, at 25 ft. intervals between the two 60 lb. charges. A hole was blasted for each 60 lb. charge by first using a 30 lb. shaped charge, as demonstrated in the 1949 expedition of the *Burton Island*. The final blast was sufficient to free the ship. Some minor damage was sustained within the ship, such as broken mirrors and light bulbs.

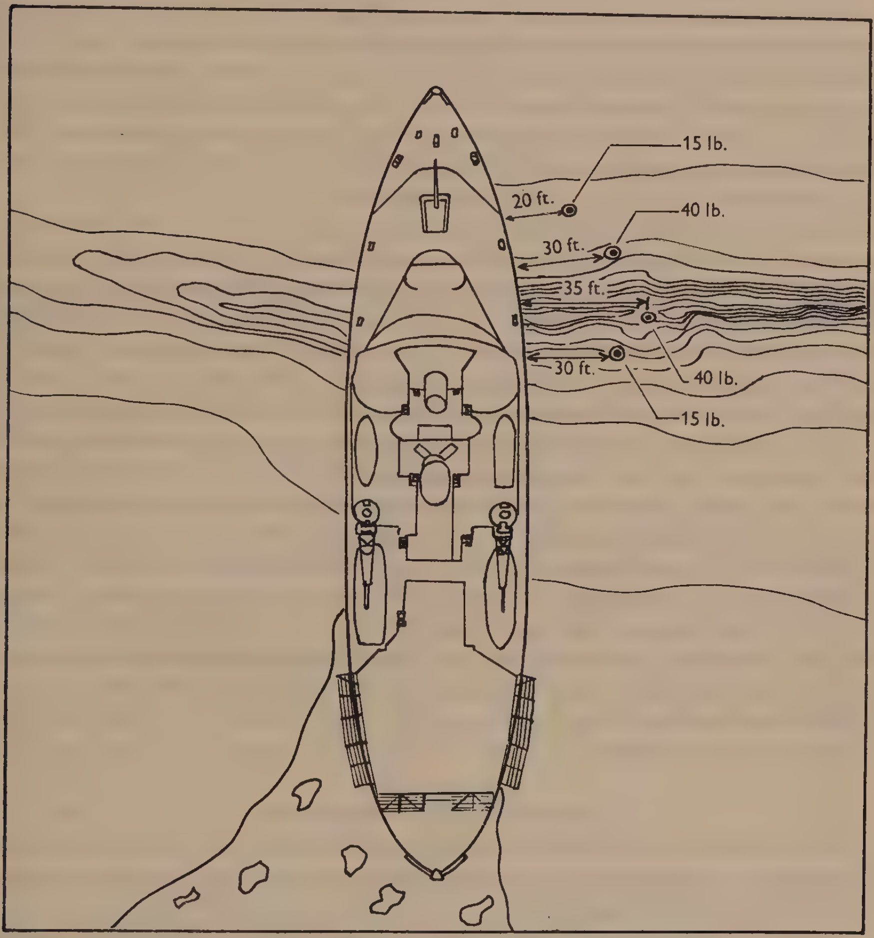


Fig. 4. Placement of 15 lb. and 40 lb. shaped charges.

The following winter, *Burton Island* again carried out oceanographic and sea ice physics work in the Bering Sea. The vessel became fast in the ice on three occasions during which the usual methods of heeling, trimming and backing failed to free the ship. On the first occasion, the attempt to use explosives was started after the vessel had been caught fast for 9 hr. She appeared to be bound by a hummock on the starboard abeam the bridge. The air temperature

was $-20°$ F. ($-29°$ C.) and a 25-knot wind was blowing. Explosive charges were set to effect a cut across the hummock area, along a line roughly parallel to the ship and at a distance of 15 to 20 ft. from the hull. Three 15 lb. shaped charges were placed along the line, 12 ft. apart, with the middle charge about at the centre of the hummock area. The firing was made while the ship was attempting to back down, heel and trim. The ship was not immediately freed, but the ice did crack about 15 min. later permitting the ship to work free.

Four days later, *Burton Island* was caught again in a hummocky area, and the demolition method was tried after the usual methods using ship power had failed to move the ship for 13 hr. The ice appeared to press in under the ship on the port side for a distance of 85 ft. The air temperature was $+20°$ F. ($-7°$ C.). Four shaped charges were placed across the hummocky area (Fig. 4). The firing was made while the ship was backing at full power, and the ship immediately broke free after the explosion.

Two days later the ship was again caught fast for 14 hr. and demolition was tried. Three shaped charges were placed at distances similar to those shown in Fig. 4. The shot was fired while the ship was under full backing power, and the ship continued to work, heeling, trimming, and backing for 45 min. after the explosion before she finally broke free. Flying ice fragments from the explosion punctured the ice sheathing of the motor whale boat on deck, shattered two port-hole glasses and pock-marked the hull in several places.

In using explosives to free the ship, it is necessary to determine the centre of the principal ice area exerting pressure against the hull and group the charges about this point. To obtain maximum effectiveness, the charges must be spaced closely and in a pattern to cut across the pressure area, roughly parallel to the ship's hull, converging slightly at the forward and after portions of the cut. Obviously, explosives cannot be effective in ice fields under lateral pressure. Only time, patience and relaxation of pressure leads to movement of the ship. However, explosives can be effective in situations where the vessel has become caught in a specific ice feature, cannot develop sufficient momentum to break free by its own power, and the explosive shock is just sufficient to weaken the ice feature.

Demolition of pressure ridges

The Bering Sea Expedition in the winter of 1954 conducted tests on the use of explosives to demolish pressure ridges in winter sea ice. A brief description of a few experiments follows:

Test (*a*). Ten lengths of bangalore torpedoes[1] were inserted into various cracks and openings in a pressure ridge, 12 ft. high, 20 ft. long and 15 ft. wide at its base. The ridge was formed in a floe 4 ft. thick. Total thickness of the pressure ridge was unknown. Air temperature was 0° F. The explosion demolished the top half of the pressure ridge only.

Test (*b*). The next test was on a pressure ridge 15 ft. high (total thickness

[1] A Bangalore torpedo is a demolition charge of $9\frac{1}{2}$ lb. of amatol in a metal tube about 5 ft. long and 2 in. in diameter. This form of demolition charge is not necessary for ice demolition work and has the disadvantage of producing shrapnel.

unknown), 40 ft. long by 20 ft. at its base, which was formed in a floe 6 ft. thick. Air temperature was −8° F. (−22° C.). First an attempt was made to blast a bore hole into the base of the ridge at an angle of about 45° to the vertical; the bore hole was then to be used to place a large demolition charge inside the base of the ridge. A 40 lb. shaped charge was used to blast the hole but, though the hole was undoubtedly created, it was covered up by a slide of loose ice that was broken free by the blast from the upper part of the ridge. Another bore hole was therefore made 6 ft. out from the base of the ridge by using a 40 lb. shaped charge. This charge penetrated the ice completely with a hole 3 ft. wide at the top, narrowing to about 8 in. across at the bottom, filled with slush and small ice fragments. Then a 380 lb., mixed charge of TNT and C-3 plastic explosive was made into a bar charge, about 8 ft. long and 8 in. square in cross-section. This charge was pushed into the bore hole, but due to the shape of the hole, only one half of the charge could be inserted, and the remainder was laid on the ice at the base of the ridge. The resulting explosion broke the pressure ridge; the part of the ridge above the surface was completely demolished, and fractures, up to 50 yd. long, formed in the floe. Ice fragments were thrown a distance of 100 yd.

Test (*c*) was made on a pressure ridge 12 ft. high, 20 ft. long and 15 ft. wide, situated in a floe 3 ft. thick. The temperature was −12° F. (−25° C.). Five 15 lb. shaped charges were used to blow bore holes. Three charges were placed in the form of a V on one side of the ridge with the apex located 12 ft. out from the ridge; the other two were placed on the opposite side of the ridge, 12 ft. apart, on a line parallel with the base of the ridge. These charges made bore holes completely penetrating the ice, 2 ft. in diameter at the top and narrowing down to 3 in. at the bottom. Five lengths of bangalore torpedoes were then inserted into each hole (i.e. $47\frac{1}{2}$ lb. amatol charge per hole), and the pressure ridge was completely broken. Ice fragments were thrown a distance of 50 yd.

Test (*d*) was made on a pressure ridge 12 ft. high, 30 ft. long and 10 ft. wide across the base, formed in a floe 6 ft. thick. The air temperature was +20° F. (−7° C.). Two bore holes were made by digging with a mattock to a depth of 4 ft. The two holes were 12 ft. apart in a line along the base of the pressure ridge, and were enlarged by detonating a $2\frac{1}{2}$ lb. TNT block on the bottom of each hole. The detonation widened the hole to a diameter of 4 ft. at the top and deepened the hole completely through to the water. A canvas-wrapped charge of 100 lb. of C-3 plastic explosive was placed in each hole. The simultaneous explosion of these two charges demolished the pressure ridge and created a pond 75 ft. in diameter, with fracture cracks extending a distance of 75 to 100 yd. on the side of the ridge that the explosion occurred. Small pieces of ice were thrown distances of 200 yd., and a visible wave was observed to travel in the ice out to a distance of at least 300 yd.

During the Bering Sea Expedition, in the spring of 1954, further attempts were made to break heavier pressure ridges by demolition. The first was a pressure ridge, 18 ft. high, 25 ft. wide and 175 yd. long, formed in a section of fast ice; ice thickness appeared to be 20 to 30 ft. The air temperature was +30° F. (−1° C.). Two holes, 18 in. deep, were dug 10 ft. from the base of the

ridge and 20 ft. apart. Charges of 5 lb. TNT were placed in each hole, tamped in with ice, and detonated. The explosions enlarged the holes to $2\frac{1}{2}$ ft. deep, with diameters of 3 ft. at the top and 4 in. at the bottom. A second 5 lb. TNT charge was detonated in each hole increasing the size to 6 ft. deep, top diameter 4 ft. and bottom diameter 4 in. A canvas-wrapped charge of 100 lb. of C-3 plastic explosive was placed in each hole and firmly tamped with ice. Simultaneous explosions created two holes, each 8 ft. deep with a top diameter of 12 ft. Ice fragments were scattered for distances up to 150 yd. The floe and ridge remained intact.

A second trial was made in a pressure ridge 18 ft. high by 15 ft. wide located in a heavily rafted area of fast ice, thickness 8 to 10 ft. (full thickness of ridge unknown). The air temperature was $+20°$ F. ($-6°$ C.). Two bore holes were made with six 30 lb. shaped charges, arranged to form two triangles, 10 ft. apart and 5 ft. out from the base of the ridge. The three charges in each triangle were 3 ft. apart. The two resulting bore holes, top diameter 4 ft., penetrated through to water, a depth of 8 ft., and were filled with slush and small ice fragments. A charge consisting of 200 lb. of TNT and 200 lb. of C-3 plastic explosive was then placed in each bore hole. The simultaneous explosions made a crater 25 ft. in diameter alongside the pressure ridge, completely filled with slush and small chunks of ice. Ice was thrown 175 yd. from the detonation. However, the pressure ridge appeared unaffected.

Conclusions

Experiments in the use of explosives in sea ice were conducted by various icebreaker expeditions to the Bering and Beaufort Seas between 1949 and 1954. The experiments were isolated tests to give a practical feel for the order of magnitude of explosive effects in sea ice. The experiments do not form a systematic knowledge of the mechanics of explosions in sea ice, nor the scaling laws for in-ice explosions, but do indicate the need for systematic study of the mechanics of explosions in relation to the physical properties of the sea ice. The experiments, though isolated, have given some practical feel for the use of explosives to assist an icebreaker in winter sea ice. It is a feeling of cautious use of explosives in very specific situations, wherein the explosive may break a particular, isolated ice feature that is blocking the ship, and not that explosives are the panacea for all beset ships. The effectiveness of explosions under sea ice warrants systematic study of these explosions.

The experiments which have been summarized were conducted by the Underwater Demolition Team (UDT) participating in each of the expeditions listed below.

(*a*) Bering Sea Expedition, Winter 1949

USS *Burton Island.*	Commanding Officer	Cdr. J. E. Gibson, USN.
	UDT Officer-in-Charge	Ltjg. W. L. Thede, USN.

(*b*) Bering Sea Expedition, Winter 1951

USS *Burton Island.*	Commanding Officer	Cdr. J. R. Schwartz, USN.
	UDT Officer-in-Charge	Lt. D. Gaither, USN.

(*c*) Beaufort Sea Expedition, Summer 1951

USS *Burton Island.*	Commanding Officer	Cdr. J. R. Schwartz, USN.
	UDT Officer-in-Charge	Lt. P. K. Clausen, USN.

(*d*) Bering Sea Expedition, Winter 1952

USS *Burton Island.*	Commanding Officer	Cdr. E. H. Maher, USN.
	UDT Officer-in-Charge	LCdr. L. A. Volse, USN.

(*e*) Joint Canadian–U.S. Beaufort Sea Expedition, Summer 1953

USCGC *Northwind.*	Commanding Officer	Capt. R. E. Morell, USCG.
	UDT Officer-in-Charge	Ens. R. W. Kausch, USN.
USS *Burton Island.*	Commanding Officer	Cdr. E. H. Maher., USN.
	UDT Officer-in-Charge	Ltjg. P. J. Koehler, USN.

(*f*) Bering Sea Expeditions, Winter and Spring, 1954

USCGC *Northwind.*	Commanding Officer	Capt. R. E. Morell, USCG.
	UDT Officer-in-Charge	Ltjg. H. W. Wile, USNR.
USS *Burton Island.*	Commanding Officer	Cdr. E. A. Trickey, USN.
	UDT Officer-in-Charge	Ltjg. D. M. Stichter, USN.

THE SECTOR PRINCIPLE IN LAW AND PRACTICE

BY OSCAR SVARLIEN*

[*MS. received 6 May 1960.*]

Though the history of polar exploration stretches over many centuries, it is only in very recent (or one might say contemporary) times that a serious interest has been shown on the part of states in the advancement of territorial claims in these perpetually frozen regions of the earth. Reasons for this new development are not difficult to find, and may, very largely, be explained in terms of economic and strategic considerations. The rapidly growing population of the world;† the pressing desire everywhere for a higher standard of living; the technological advancement in transportation and communication; new geographic conceptions, and a modern strategy of military operations are all factors which help to clarify this phenomenon. As a result of these and many other recent developments, which we shall not attempt to catalogue here, it is not unreasonable to assume that the polar regions will in the future become more rather than less important in world affairs.

With respect to territorial claims in general there are certain well established and controlling norms in international law. These, however, are not of a character eternal and unchangeable, but have been subject to a certain evolution over the centuries. Before the sixteenth century, for example, territorial acquisition was based in the main upon papal grants. But both in the sixteenth and seventeenth centuries the British, the French and the Dutch, who refused to recognize the papal grants to Spain and Portugal, based their respective claims upon discovery and occupation. It was not until the eighteenth century that the principle of *effective occupation* became firmly established. This last doctrine was advanced in connexion with the partition of Africa (the Berlin Act) in the latter part of the nineteenth century.[1] The meaning of the phrase "effective occupation" is not altogether clear. It seems to have been more liberally construed in some cases than in others. In the East Greenland Case,[2] for example, the Permanent Court of International Justice pointed out that two factors are involved in the acquisition of title by occupation, namely, "the intention or will to act as sovereign, and some actual exercises or display of authority". The Court was satisfied on the basis of evidence that, from the year 1721 to 1931, Danish claims to sovereignty over the whole of Greenland had never been challenged by any other nation, and went on to say: "It is impossible to read the records of the decisions in cases as to territorial sovereignty without observing that in many cases the tribunal has been satisfied with very little in the way of the actual exercise of sovereign rights, provided that the other state could not make out a superior

* Department of Political Science, University of Florida.

† The estimated growth of the world's population is at a rate well in excess of 30 millions a year.

claim. This is particularly true in the case of claims to sovereignty over areas in thinly populated or unsettled countries."

According to Charles Cheney Hyde: "The acquisition of rights of sovereignty over polar areas is complicated by four considerations: first the circumstance that the objective, especially in the Arctic regions, may be an area of which the surface above the level of the sea is ice rather than land; secondly, the preferment of initial claims is made at a time when the requirements of international law in relation to the acquisition of original rights of sovereignty are fairly well understood, and yet which in the course of their evolution there has been slight occasion to apply or adapt to polar areas; thirdly, the existing inability of a claimant State, by reason of climatic conditions, to attain such a kind and degree of control over a polar region as is acknowledged to be essential for the perfecting of a right of sovereignty over an area in non-polar regions; and, fourthly, the fact that certain polar areas are a natural or geographical prolongation of others outside thereof which are acknowledged to belong to particular States."[3]

It has been pointed out by some writers that with respect to territorial claims in the polar regions, because of their peculiar geographic and climatic conditions, the international–legal requirement of "effective occupation" is in many cases quite impossible of fulfilment.[4] For this reason it is argued that the present three-pronged criterion of discovery, occupation and notification* should be modified when applied to areas within the Arctic and the Antarctic. There seems to be fairly general agreement, however, to the effect that if there are to be certain relaxations of legal requirements for territorial claims because of special conditions, such changes in the law can have no general application. According to Hyde: "The relaxation should be confined to the waiving of settlement as a necessary condition for the perfecting of a right of sovereignty, provided a claimant state may establish that by some other process it is in a position to exercise control over what it claims as its own."[5] It should be noted that in the East Greenland Case,[6] the Permanent Court of International Justice held that Denmark could not be expected to exercise continuous and vigorous authority over all of Greenland because of the rigorous climate and the inaccessible nature of that Arctic island. It might be said, therefore, that the unique and difficult geographic environment of the polar regions is of such a nature as to preclude full application of the generally accepted legal norms with respect to the acquisition of territory. Attempts to devise new techniques for the solution of this problem have, therefore, been made, and the most interesting of these is known in our literature as the "sector principle".

A complete and clear definition of the sector in polar regions has been given by the Norwegian authority, Gustav Smedal, as follows: "In spherical geometry, a sector is a part of the surface of a sphere limited by a piece of curve line and two great circles crossing each other and drawn through the extreme points of the curve line. When applied to the surface of the globe, a polar

* Notification to the Powers is provided for in Article 34 of the Act of Berlin 1885. But see on this point the Clipperton Island Case. *American Journal of International Law*, Vol. 26, 1932, p. 290.

sector is a special instance of this general definition, limited by a piece of curve line, e.g., a coast line, and the meridians through the extreme points of the curve line. It is in this meaning that the word 'sector' is applied in the conception of the sector principle."[7]

The earliest mention of this principle in connexion with territorial claims in polar regions dates from 1907. It was on 20 February of that year that Senator Poirier presented the following motion in the Canadian Senate: "That it be resolved that the Senate is of opinion that the time has come for Canada to make a formal declaration of possession of the lands and islands situated in the north of the Dominion, and extending to the North Pole."[8] In the course of presenting this resolution, Senator Poirier made a speech in which he contended that "in future partition of northern lands, a country whose possession to-day goes up to the Arctic regions, will have a right, or should have a right, or has a right to all the lands that are to be found in the waters between a line extending from its eastern extremity north, and another line extending from the western extremity north. All lands between the two lines up to the North Pole should belong and do belong to the country whose territory abuts up there."[9]

Senator Poirier, employing the principle he had just stated, went on to assign respective "polar sectors" to Canada, the United States (based on Alaska), Russia, Norway and Sweden. He contended that "this partition of the polar regions seems to be the most natural, because it is simply a geographical one. By that means difficulties would be avoided, and there would be no cause for trouble between interested countries. Every country bordering on the Arctic regions would simply extend its possessions up to the North Pole."[10]

Even though Poirier's motion failed of adoption at the time,[11] it constituted a significant first statement and definition of the principle. The Soviet writer, V. L. Lakhtin, conceives of a polar sector as a triangular area of "terrestrial gravitation", or region of attraction formed by a state adjacent to the Arctic, and limited by the northern coastline of that state and the meridians crossing the western and eastern extremities of this line. He also contends that this principle is already "established by contemporary Arctic international law", and that the term "sector" is now definitely admitted in literature and is used by all those engaged in the study of the problem.[12] If the projection of a line delimiting a sector encounters the territory of another state, however, a deviation of the line is necessary. This occurs in the case of Canada when the line on its eastern frontier, at long. 60° W., would otherwise intersect western Greenland. The same is also true of the Norwegian Svalbard archipelago which projects across long. 32° 4′ 35″ E. and necessitates a deviation in the line delimiting the western boundary of the Soviet sector. From these definitions of the "sector principle," it would appear that there is general agreement as far as the verbal description of what constitutes a "sector" is concerned. It is less clear, however, what the meaning of this principle is in actual application.

The "sector principle" was primarily intended, by its author, as a means to

the solution of territorial claims problems in the Arctic. It was presumably designed as an interposition to territorial claims by other states as a result of their explorations among the islands to the north of Canada. In this connexion we might mention the voyages of the famous Norwegian polar explorers, Roald Amundsen and Otto Sverdrup, who in the nine years 1898 to 1906 made discoveries which "added almost as much new land and sea to Canada's future Northwest Territories as all the ships of the thirty-year Franklin Search"[13] But in spite of the fact that the "sector principle" was designed for the northern polar regions, it is in the South that we find its first real application.

By Letters Patent on 21 July 1908 South Georgia, the South Shetland Islands, the South Sandwich Islands, the South Orkney Islands, and that part of Antarctica which the British call Graham Land were all made dependencies of the Falkland Islands.[14] Though this may not, in a strict sense, be regarded as an application of the "sector principle" as a means to delimitation of territory, it is certainly a pointer in that direction. This can be seen from the language in an Ordinance enacted by the Governor of the Falkland Islands with the advice and consent of the Legislative Council thereof on 22 December 1908. Article 1 of this Ordinance reads as follows:

> In this Ordinance, and in all Ordinances passed after the commencement of this Ordinance, unless the contrary intention appears, the expression "Dependencies" shall mean the groups of islands known as South Georgia, the South Orkneys, the South Shetlands, and the Sandwich Islands, and the territory known as Graham's Land, situated in the South Atlantic Ocean to the south of the fiftieth parallel of south latitude, and lying between the twentieth and the eightieth degrees of west longitude.[15]

British Letters Patent, passed under the Great Seal of the United Kingdom, and bearing the date of 28 March 1917, provided for a further definition and administration of certain islands and territories as dependencies of the Colony of the Falkland Islands. They provide that "the Dependencies of our said Colony shall be deemed to include and to have included all islands and territories whatsoever between the 20th degree of west longitude and the 50th parallel of south latitude; and all islands and territories whatsoever between the 50th degree of west longitude and the 80th degree of west longitude which are situated south of the 58th parallel of south latitude".[16]

The technique contained in the sector principle is again resorted to by the British in the territorial delimitation of the Ross Dependency. This embraces an area between the South Pole and lat. 60° S. delimited east and west respectively by the meridians at long. 160° E. and long. 150° W.; and this vast territory has been assigned to New Zealand.[17] Ten years later, another British Order in Council placed a large Antarctic sector under the authority of the Commonwealth of Australia. It proclaimed that "that part of the territory in the Antarctic Seas which comprises all the islands and territories other than Adélie Land situated south of the 60th degree of South Latitude and lying between the 160th degree of East Longitude and the 45th degree of East Longitude is territory over which His Majesty has sovereign rights".[18]

The French claim in Antarctica was initially based on discovery by the

intrepid Admiral Dumont d'Urville in 1840, who named a portion of the Antarctic coast, which he then sighted, in honour of his wife, Adélie. No territorial claims were made, however, until 1924 when two decrees issued by the French laid claim to Terre Adélie. The first of these decrees came on 27 March 1924 in which territorial claim based on discovery was stated. This was followed by a second decree on 21 November 1924 which placed Terre Adélie under the government of Madagascar, along with the islands of St Paul, Amsterdam, and Kerguelen, as well as the Isles Crozet. A later decree of 1 April 1938, however, makes use of the "sector principle" in defining the French claim. Article 1 of this decree reads in translation as follows: "The islands and territories situated to the South of the 60th parallel of South Latitude and between the 136th and 142nd meridians of Longitude East of Greenwich are under French sovereignty".[19]

Aside from the Antarctic sector claims of the British and the French, there are also Norwegian, Chilean, and Argentine claims, all of which are defined in terms of geographic sectors. A Norwegian Royal Decree of 14 January 1939 laid claim to a sector on the Antarctic continent between the Weddell Sea and Enderby Land. It was specifically defined as: "That part of the mainland coast in the Antarctic which extends from the Falkland Island Dependencies in the west (the boundary of Coats Land) to the boundary of the Australian Antarctic Dependency in the east (long. 45° E.) together with the land situated inside this shore and the sea adjacent thereto is brought under Norwegian sovereignty."[20] The territory is known as Dronning Maud Land.

With respect to the sector claims in the Antarctic that we have described above, there is mutual recognition by the claimant states, and so far no dispute appertaining thereto has ever arisen. But as we shall see later, this is only true so long as the Chilean and Argentine claims are not taken into consideration. Chile and Argentina rely heavily for their territorial claims in the Antarctic on two principles, both of which are of doubtful pertinence, namely that of *uti possidetis*[21] and the principle of geographic propinquity. Nevertheless, the "sector" is resorted to by both countries in defining their overlapping territorial claims.

In a decree under the date of 6 November 1940, issued by the government in Santiago, it is stated that: "All lands, islets, reef or rock, glaciers (pack ice), already known or to be discovered, and their respective territorial waters, in the sector between longitudes 53 and 90 West, constitute Chilean Antarctica or Chilean Antarctic territory."[22] Inasmuch as Chile had always based her claims to territory in the Antarctic on geographical and historical grounds, the function of this decree, according to de la Barra, was "to fix with accuracy the limits of a sovereignty that had existed since the XVI Century".[23]

The first official Argentine claim to Antarctic territory seems to have been made in a statement before the Universal Postal Union in 1927, announcing that: "Argentine territorial jurisdiction extends in fact and in right over the continental area, the territorial sea and the islands of Tierra del Fuego, the archipelagos of Estados, Año Nuevo, South Georgia and the polar lands not yet delimited."[24] Argentine official opinion was at first opposed to the "sector

principle" as a technique for defining and delimiting territorial claims in the Antarctic. It is suggested that this point of view was inspired to a certain extent by the fact that the British had made use of this principle in the delimitation of the Falkland Islands Dependencies.[25] As early as 1942, however, in connexion with the *Primero de Mayo* expedition, an unofficial use is made of the sector principle in proclaiming the annexation of all territory between longs. 25° and 68° 34′ W. to the south of lat. 60° S. In 1946 this claim was extended to include all regions between longs. 25° and 74° W. and south of lat. 60° S. This sector was given the official name of Antártida Argentina.[26] In certain reservations made in 1951 to the Final Protocol enacted by the Extraordinary Administrative Radio Conference at Geneva, Argentina, again making use of the "sector principle" defined its Antarctic territory as located "between longitudes 25° and 74° West of Greenwich, South of latitude 60° South as far as the South Pole".[27] Furthermore, by the Decree-Law No. 2191, published in the *Bolétin Oficial* (Buenos Aires) of 19 March 1957, the same sector definition as given above is repeated. It should be noted, however, that the Argentine claim overlaps the Chilean sector which, as we have indicated above, stretches between longs. 53° and 90° W. Likewise, both the Argentine and the Chilean claims overlap the much earlier defined British sector of the Falkland Islands Dependencies. Because of this confusing situation a "cold war" has raged for the last decade and a half between Great Britain, Argentina and Chile. Sovereignty placards in bronze have been put up and torn down, and warships have even made their appearance in the ice-filled seas of this region.[28]

The claims which we have delineated above leave unclaimed only that portion of the Antarctic which lies between the New Zealand and Chilean sectors or between longs. 90° and 150° W. This region, of which a large part is known as Marie Byrd Land, has been extensively explored by the Americans and claimed for the United States by Admiral Richard E. Byrd.[29] No official claims to this or any other region in the Antarctic has ever been made by the United States Government. On 6 January 1939, however, the Department of State, referring to notes exchanged between the British and French Governments, instructed the American Embassies in London and Paris to inform the British and French that the United States Government reserved all rights of its own or its citizens "with respect both to the question of aerial navigation in the Antarctic and to those underlying questions of territorial sovereignty involved".[30] It should be noted, furthermore, that the United States Government has consistently refused to recognize any territorial claims by other states in the region of the Antarctic.

Before proceeding to a legal evaluation or critique of the "sector principle" as a means to territorial delimitation generally in polar regions, it is necessary to take a brief look at its present status in the Arctic. It is quite clear that when Poirier first propounded the sector theory, he did not have in mind the then relatively unknown Antarctic, but was concerned in the main, as we have suggested above, with preventing any territorial interposition by foreign powers in the vast and, to some extent, unexplored region to the north of

Canada. Though the Canadian Government showed a certain reluctance to follow-up Poirier's suggestion, the principle, fortified by its strong logic, did persist in the minds of men. And, as we have already seen, in 1917, the British applied it for the first time in defining the Falkland Islands Dependencies.

The first official claim to territory in the Arctic involving the sector principle did not come from Canada but from the Soviet Union. It has been said by Russian writers on international law that, in making use of the "sector principle" for purposes of territorial claims in the Arctic, the Soviet Union was merely following "the example of Great Britain in the Antarctic regions".[31] Be this as it may, on 15 April 1926, the Presidium of the Central Executive Committee of the U.S.S.R. issued a decree employing the sector principle as a basis for territorial claims in the Arctic. It provided as follows:

> All lands and islands already discovered, as well as those which are to be discovered in the future, which at the time of the publication of the present decree are not recognized by the Union of Socialist Soviet Republics as the territory of any foreign state, and which lie in the Northern Frozen Ocean north of the coast of the Union of Socialist Soviet Republics up to the North Pole, within the limits between the meridian long. 32° 4′ 35″ E. from Greenwich, which passes along the eastern side of Vaida Bay through the triangular mark on the Kekurski Cape, and the meridian of long. 168° 49′ 30″ W. from Greenwich, which passes along the middle of the strait separating Ratmanoff and Krutzenshtern (sic.) Islands from the group of Diomede Islands in Bering Straits.[32]

Although this is the first and only official application of the "sector principle" in the Arctic, its rational, which is that of territorial propinquity and continuity, is discernible in earlier enactments. On 29 September 1916 the Russian Government issued a declaration stating that several islands north of the Siberian mainland were to be regarded as part of the Russian Empire on the grounds that they form "the northern continuation of the Siberian continental shelf".[33] This declaration was, in substance, repeated by the Soviet Government in a memorandum on 4 November 1924.[34] It is the decree of 15 April 1926, however, that concerns us here, as it is this enactment by the Central Executive Committee of the Soviet Union that makes use of the "sector principle" in the delimitation of territorial claims. It might be noted that on 10 June 1925, Mr Stewart, Canadian Minister of the Interior, making use of the sector principle, again defined the Dominion's Arctic Territory.

As we have already indicated at the beginning of this inquiry, the legal norms relative to the acquisition of territory have not remained static, but have undergone significant changes in course of time. It has also been suggested that because of the uniqueness of geography and climate in polar regions there ought to be, and in fact has been, a certain relaxation of accepted norms with respect to territorial claims in those areas. This, as we have seen is particularly well illustrated in the East Greenland Case. But it is not only the peculiar geographical conditions of the Arctic and Antarctic that are of significance here. We cannot ignore the technological revolution of the last half century, which has contributed so much to make the polar regions not only less remote, but also less inhospitable to man's habitation.

Although the Arctic and the Antarctic are very different from any other portion of the globe as far as climate is concerned, the two regions have little in common geographically. Antarctica is a continent about twice as large as Australia, weighted down by an incalculable mass of ice and snow, and surrounded by the waters of the Atlantic, the Pacific and the Indian Oceans. The central Arctic, on the other hand, constitutes a deep ocean with superincumbent and constantly drifting ice. It is a veritable Mediterranean, almost completely surrounded by the North American and Eurasian land-masses. The restless pack ice of the Arctic Ocean, which in the past provided so great a hazard to navigation, is to-day in the face of new means of transportation, far less formidable. The advent of modern aircraft lent a new significance to the fact that the shortest route between Washington and Moscow lies over the Arctic. Furthermore, Vilhjalmur Stefansson's once fantastic dream of submarine navigation under the Arctic ice is to-day a reality. In view of the many recent technological developments, the polar regions, and particularly the Arctic, have acquired a strategic importance that they did not have before. It is this fact, perhaps more than any other, that has inspired "territorial claims to lands and islands, both known and unknown",[35] which lie within these regions. As we have already seen, it is in connexion with such claims both in the Arctic and in the Antarctic that the "sector principle" has been resorted to as a facility in defining areas over which sovereignty has been proclaimed by a number of states. It now remains to enquire more closely into the precise meaning to this principle and to assess its validity in terms of international law.

A juristic theory which seeks to provide a plausible rationale for the "sector principle" has been advanced by Lindley, who relates the "sector" to the principle of the "hinterland".[36] This argument, however, finds little or no support in the law of nations, at least as this law is understood and applied to-day. The principle of the so-called "hinterland" whenever it was resorted to, as in the nineteenth-century African partitions,[37] always referred to territories stretching inland from the coast and never to lands and islands to the seaward off the coast.[38] An argument in favour of this principle is provided in connexion with a dispute between the United States and Spain in 1805 relating to the boundaries of Louisiana. The United States did at that time maintain that: "When any European nation takes possession of any extensive sea-coast, that possession is understood as extending into the interior country to the sources of the rivers emptying within that coast, to all their branches and the country they cover."[39]

David Hunter Miller, who like Gustav Smedal objects to the use of the term "hinterland" in connexion with territorial claims in the Arctic, suggests instead that such claims might simply be made on the basis of "territorial propinquity";[40] that is to say on the basis of nearness to the main and undisputed territorial possessions of the state in question. In connexion with claims to territory lying off the coasts of the main-land, the term "contiguity" is not only more generally used but furnishes, within certain limits, a somewhat better basis for the claims. It was certainly this doctrine which was resorted to

by the Russians in the Imperial Declaration of 29 September 1916, in which, as we have already seen, a number of islands to the north of Siberia were regarded as forming an extension of the continental shelf. The question which at once presents itself is: What are the geographical limits within which the principle of "contiguity" or "continuity" can reasonably be applied? To this there is, as far as we know, no answer in the contemporary law of nations, and each case, therefore, would have to be settled as between the interested parties. It is quite clear also that any such settlement would create no binding legal norms except as between the parties to the agreement.

A careful study of the arguments of the proponents of the "sector principle", in the Arctic at least, would seem to indicate that the territorial claims here are based largely on the principle of contiguity, or as the Soviet authority, Lakhtin, puts it, "regions of attraction".[41] The same could not be said for the Antarctic. Here, the peculiar geographical conditions which we have alluded to above, do not allow application of the "sector principle" in the same manner as in the Arctic. If Antarctic claims, like those in the Arctic, were to be determined by the extension of the meridians by which southern countries are bounded in east and west to the polar intersection of such meridians, most of the Antarctic continent would be unclaimed. Furthermore, the vast expanse of ocean intervening between established sovereignties in the south and the Antarctic lands and islands would render the principle of contiguity inapplicable. But what is the situation with respect to Argentina and Chile? The answer here seems to be that even though those countries extend farther south than any others, they do not project across the Antarctic Circle. Moreover, since several hundred miles of open sea separate the mainland of both Argentina and Chile from Antarctic territory, it would not be possible to apply the principle of "attraction" or contiguity in a sector claim. Since this is even more true of other states, claimant to Antarctic territory, it is not surprising to find an application of the "sector principle" here quite different from the one used in the far north. As Robert D. Hayton puts it in a recent article in the *American Journal of International Law*: "As it is, the Antarctic sectors are based on an arbitrary Parallel on the high seas and project towards an alien mainland."[42]

Not since Pope Alexander VI issued his bull *Inter Caetera*, dividing whole oceans and continents between Portugal and Spain, have such arbitrary methods been used in territorial division. There can be no doubt whatever that the methods employed here are without foundation in the law of nations. Even if the maritime and insular portions of the Antarctic sectors are left out of consideration, and the base lines of the various sectors moved south to the main coast of the continent such sectoral division could find no justification in existing law. In the latter case, of course, the argument might be made that discovery of a certain amount of coast line could give a right to territorial claims there, which could then be projected towards the Pole on the basis of the "hinterland" principle, and the territory thus claimed bounded by the meridians delimiting the length of coast line claimed in each case. Such a solution of the problem would, however, be quite impossible, not only on legal

but on practical grounds. In the first place, it would be extremely difficult to determine in every case who would be entitled to inchoate title by virtue of discovery. This is a matter around which there rages much uncertainty and confusion. In the second place, the use of the so-called "hinterland principle" as a foundation for land claims interior to the coasts seems to find no contemporary sanction in international law. As Mr Olney, a former American Secretary of State, said in connexion with the partition of Africa in the late nineteenth century: "It cannot be irrelevant to remark that 'spheres of influence' and the theory or practice of the 'Hinterland' idea are things unknown to international law and do not as yet rest upon any recognized principles of either international or municipal law."[43]

Inasmuch as in the Arctic the geographical situation is very different from that in the South Polar regions, the question presents itself as to whether the "sector principle" cannot here find a better support as a facility to territorial division between states. Even though the Arctic Ocean is for the most part surrounded by the curved coasts of Eurasia and North America, it is not an inland sea. It is a large and deep ocean open at both ends; on the western side by the Bering Strait and on the eastern side by the Norwegian and Greenland Seas. Therefore, it would seem that apart from the fact that its waters are largely covered by drifting ice of various formations, the Arctic Ocean cannot be regarded as in any way different from any other of the high seas. In our time, with atomic submarines and icebreakers and various kinds of aircraft, it is quite clear that the Arctic Ocean no longer constitutes the barrier that it once did.

The shores of the Arctic Ocean are at the moment shared by five states. These are the USSR, the Dominion of Canada, the United States of America, Denmark, and Norway. About one half of the Arctic shoreline is under the sovereignty of the USSR, while of the other half Canada has the lion's share. Only very modest portions fall to the remaining three powers. This may be one of the reasons why the USSR and Canada are favourably disposed to a sectoral division of the Arctic Ocean, while the United States and the two Scandinavian countries are opposed to this method. But what is the real meaning of the "sector principle"—its ultimate comprehension? What are its legal foundations?

There seems to be disagreement among the authorities, and it is not at all clear what is included in a "sector" or "area of attraction". Is the area thus claimed, or which would be claimed, confined to lands and islands, or does ice, sea and air regions as well fall within the concept of the "sector"? Even though the Soviet decree of 15 April 1926 makes no mention of territory other than "all lands and islands already discovered, as well as those which are to be discovered in the future", the meaning of what is comprehended here has been variously interpreted. The general opinion of Soviet authorities seems to include the waters of the Arctic Ocean under the sovereignty of the littoral states.[44] Breitfus argues that the Polar States are entitled to sovereignty, subject to a more precise definition of international law, not only over lands and islands, but also over the sea and ice surrounding them.[45] Professor

Korovin, in reference to the Soviet decree of 1926, regards it as unfortunate that only "lands and islands" are mentioned. He contends that "this Decree must be understood to include in the conception of 'lands and islands', as expressed by Soviet legislators, also ice formations and the seas surrounding them, for otherwise the polar sector adjacent to the USSR would have to be considered as an open sea with all the consequences resulting from such an interpretation".[46] Sigrist, in referring to the same decree, has this to say:

"Interpreting this decree from the standpoint of the underlying idea, and not literally, we must admit that to the USSR belong not only 'lands and islands already discovered and those which may be discovered in the future', but also the areas among them irrespective whether there be there immobile or floating ice, or permanently frozen lands still unknown to us, for otherwise foreigners might think that between these islands there was 'open sea', free for exploitation by every nation. In the spirit of the Decree we must maintain that the whole region from the Soviet mainland to the Pole is Soviet possession, even if it is just as difficult to go there as to climb the summits of the Caucasian, Ural, Altaian or other mountains the Soviet ownership of which has never been disputed."[47]

V. L. Lakhtin, another Soviet writer, summarizes his point of view as follows:

(1) Polar States wield sovereignty over sea regions covered with ice, according to their sectors of attraction.

(2) Littoral States wield sovereignty over landlocked seas free from ice, and over gulf and bays.

(3) Littoral States are entitled to a somewhat limited sovereignty over all remaining sea regions free from ice, as well as over territorial waters, maritime belts and waters between islands according to their sectors of attraction.[48]

With respect to the air region of the Arctic, it is the opinion of both Lakhtin and Breitfuss that each Polar State has complete sovereignty over the air-space within the whole region of its sector.[49] From what has been said so far it would appear that Soviet publicists are seeking legal justification for converting a very substantial part of the *terra nullius* of the Arctic into an exclusive domain of the USSR from which foreign powers may be effectively excluded. The device used to this end is the 'sector principle" which, as we have suggested above, is derived from the nineteenth-century doctrine of contiguity. But in the Island of Palmas Case, Max Huber denounced this doctrine by saying: "Although States have in certain circumstances maintained that islands relatively close to their shores belonged to them in virtue of their geographical situation, it is impossible to show the existence of a rule of positive international law to the effect that islands situated outside territorial waters should belong to a State from the mere fact that its territory forms the *terra firma* (nearest continent or island of considerable size). Not only would it seem that there are no precedents sufficiently frequent and sufficiently precise in their bearing to establish such a rule of international law, but the alleged principle itself is by its very nature so uncertain and contested that even Governments of the same State have on occasions maintained contradictory opinions as to its soundness."[50]

Lakhtin divides the seas lying within the Arctic Circle into two classes as follows: "first, seas covered with more or less immovable ice formations of considerable size; and, second, seas free from any ice cover."[51] It is unlikely that this imprecise definition of ice formations in the Arctic is due to ignorance, on Lakhtin's part, of the physical conditions there; rather it must be attributed to a design which will allow for considerable political flexibility. It is well known, and Lakhtin must have been aware of it, that the Arctic ice is, in the main, divided into three types: (1) the fast ice; (2) the open pack ice; and (3) the close pack ice. In this order, generally, as one proceeds from the northern coast lands towards the central Arctic basin. Or according to the Russian oceanographer Transehe: "The main mass that fills the central and largest part of the Arctic Sea constitutes the Arctic Pack. The two other classes occupy concentric belts around the Arctic Pack—the fast ice, the outer belt, and the pack ice, the belt between the fast ice and the Arctic Pack."[52] A true and complete classification of the various ice formations in the Arctic is, of course, far more complex than those given above,[53] but not of great importance in throwing light on the present problem. The great difficulty with Lakhtin's classification is that only the fast ice is stationary (though it varies in extent between summer and winter), while the open pack ice and the close pack ice are constantly drifting with wind and current. Lakhtin's definition, according to Taracouzio: "suggests no criteria either for differentiating 'floating ice' from 'more or less immobile ice', nor for determining the latter. Yet, . . ., the former 'should be assimilated legally to open polar seas', while the latter is subject to the sovereignty of the Littoral State."[54]

In view of the existing physical conditions in the Arctic, it would appear that Lakhtin's definitions are no less unreasonable in theory than they would be unworkable in practice. The whole history of Arctic travel, to say nothing of continuous observations at the present time, shows very clearly the instability of the surface of the polar ocean. It shows, for example, that waters which at one time are "free from any ice cover", may quite suddenly, due to a shifting wind, be filled with ice formations of "considerable size". It shows that great ice islands, often many miles in circumference, providing ideal camp sites for scientific expeditions, are not stationary but may, within the course of their lifetime, drift many thousands of miles through the various sectors of the Arctic Ocean.

An even more confusing problem presents itself in Lakhtin's definition of territorial waters. Are the twelve miles which the Soviets claim to be measured from the mean low water on shore or from the outer edge of the ice shelf, that is to say, the ice port? Among the waters over which the littoral state has sovereignty, Lakhtin includes: "mouths of rivers, bays and land-locked seas with an entrance which in theory is not wider than twice the width of marginal seas."[55] Under the concept "territorial waters" are also included "the waters lying between the islands and archipelagoes".[56] This would seem to include, in large part, what is quite universally regarded as the high seas. Any further elaboration of Lakhtin's theories here only adds confusion.

It would seem from what has already been said that there is little to choose between the extreme position of Sigrist and Korovin, on the one hand, as to what is comprehended by the "sector principle" in the Arctic, and the less arbitrary but more confusing precepts of Lakhtin. In any case, the category of high seas would quite completely be eliminated from the Arctic. But the difficulty of the doctrine, according to Taracouzio, "lies not so much in the dogmatics of the problem, as in the materialization of the changes necessary for the sanction of this theory either by modification of the existing doctrine, or by exemption of the Arctic from the rules of international law now in force".[57]

A number of Soviet writers have referred to certain boundary treaties and diplomatic exchanges in order to show general acceptance of the "sector principle". Among these are the Convention between Great Britain and Russia of 1825 and the United States–Russian Treaty of 1867. The last named treaty defined the western boundaries of Alaska as passing "through a point in Bering's Strait on the parallel of 65° 30′ north latitude, at its intersection by the meridian which passes midway between the islands of Kruzenshtern or Iganalook, and the Island of Ratmanov, or Noonarbook, and proceeds due north, without limitation, into the same Frozen Ocean".[58] Article 3 of the 1925 convention stipulates that the "Meridian Line of the 141st degree, in its prolongation as far as the Frozen Ocean, shall form the limit between the Russian and British Possessions on the Continent of America to the North-West".[59]

The significance of these treaties as supporting documents for the "sector principle" hinges on the interpretation of such phrases as "into the Frozen Ocean", and "as far as the Frozen Ocean". Does this mean to the Arctic Ocean, or does the boundary continue along the designated meridian until it reaches the North Pole? The question may also be raised as to whether the phrase "without limitation" means to the North Pole, as an astronomical line such as a meridian cannot be limited at any other point. Whatever the intention may have been, expressions such as these, when used in diplomatic documents, are certainly useful as arguments in support of the "sector principle". But even if we assume that it was the intention of the parties to these treaties to divide the Arctic between them, such bilateral arrangements would not be binding on other states.[60]

From all we have said so far the conclusion must be that there exists no legal foundation in support of the "sector principle" either in the Arctic or in the Antarctic. Yet we are tempted to suggest that in the Arctic, at least, the "sector principle" of territorial claims, if confined to lands and islands within the respective sectors, is sufficiently in accord with the inevitable to make its tacit adoption highly probable. This certainly would have little or no effect on the *status quo* with respect to territorial claims within the Arctic region. On the other hand, if the sector claims are to include not only the "lands and islands", but also the open and ice-filled ocean and the superincumbent air-space, as has been suggested by some Soviet writers, then it must be rejected as unworkable both on legal and political grounds. The Arctic Ocean cannot

be regarded as in the category of the Caspian Sea or the American Great Lakes. It is not an inland sea. It is connected with both the Atlantic and the Pacific Oceans by open and navigable waters. The well-established principle of the freedom of the high seas applies no less to the Arctic than to any other ocean. The fact that a large portion of the polar seas are covered with ice of various formations does not justify their assimilation to the land surface of the globe. Furthermore, the condition of the polar ice is such as to make territorial claims through effective occupation impossible because the ice surface of the Arctic Ocean is constantly shifting and moving with currents and winds. A Russian station on the polar ice might after a lapse of time find itself located deep within the "Canadian sector". For this reason the "sector principle" is unworkable when applied to the ice. It would seem quite clear, therefore, that the floating ice formations, of whatever classification, must from a legal point of view be regarded as a part of the ocean itself. Thus in conformity with the principle of the freedom of the seas, there can be no territorial claim to any part of the Arctic Ocean.

This whole problem is further complicated by the fact that at the present time there is a tendency on the part of many states to extend their sovereignty into the high seas through a unilateral expansion of the territorial waters. The old argument that the high seas could not be effectively defended, and that they could therefore not be claimed by any nation, is an argument that can no longer be sustained. Thus if the oceans of the world are to remain open to all nations, international control may be necessary. It is suggested, therefore, that a beginning be made in the Arctic. A convention, in which the sector principle is recognized with respect to the territorial apportionment of the Arctic lands and islands among the subjacent Polar States, subject to long-standing economic rights of foreigners in such lands and islands, would serve this end. Such a convention should also contain specific provisions to the effect that this apportionment of territory shall not apply to any part of the open or frozen ocean, nor to the superincumbent airspace. In this way a compromise may be made between the principle of effective occupation, on the one hand, and that of the sector principle on the other.

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SPITSBERGEN CHARACTERS

BY R. N. RUDMOSE BROWN

[This article was found among the papers of the late Robert Neal Rudmose Brown, who bequeathed his library to the Scott Polar Research Institute in 1957. It is published by kind permission of his daughter, Mrs Jean Brown. Brown accompanied Dr William Spiers Bruce four times to Spitsbergen, in 1909, 1912, 1919 and 1920. Place-names have been modernized to the present official Norwegian forms. Ann Savours.]

Beachcombers usually are associated with tropical islands, with hot sandy foreshores and coral reefs, backed by waving palms and jungle-clad slopes. They conjure up an atmosphere of dusky maidens and pearls and the other features of a lazy lotus land. But wherever ordered life frays out on the edges of civilization, the beachcomber makes his appearance. He likes comfort, but cheerfully accepts inconvenience provided only that he can escape a life of rules and ordered conventions: he seeks a measure of freedom far beyond the dreams of the noisy democrat. The untrammelled life that the unsocial beachcomber seeks is not impossible in Spitsbergen: true, conditions are not such as would attract lovers of warmth and comfort in every hour of existence, but a nomad's life in the Arctic has not all the discomforts that the inexperienced might believe.

H. had caught the lure of the Arctic in a summer's surveying expedition: he learned to value its peace and freedom and to enjoy its exhilaration and austere beauty. A domestic blow sent him back to Spitsbergen to live alone with his memories but away from people who were perpetual irritants. In summer months he lived generally in his tent on green slopes in sheltered coves. He knew where to find ptarmigan, duck, geese and reindeer; driftwood was his fuel. As soon as one place tired him he moved on in his boat. The west coast and Isfjorden saw little of him in summer for he had no desire to meet people. The north was more lonely and had more game. H. seldom travelled far inland: glaciers had nothing to offer him and the sea was his highway. Occasionally he was sighted by a vessel but a reluctant wave was his only reply to a hail. He had no desire for human companionship. When winter came down on the land he chose an abandoned hut, built perhaps by hunter or prospector, and there settled down for some eight months. He hunted for his food and collected a few skins, for skins were his only currency. He read nothing to speak of and his time was fully occupied in daily tasks of his lonely home. His hut was tidily kept and eventually left in better condition than he found it. Very rarely he had a winter journey to a mining settlement to get a little tea, coffee, sugar and flour or perhaps a few clothes. His needs were small and his stay was short. The warmth and comradeship of the miners' settlement had no allurement for H. He was not sulky or even ungenerous but always taciturn and he rarely had a smile for anyone. Weather did not deter him; his simple business done, he was off again and rarely did one know where

he was going. It was a rough life but not very dangerous. H. had a tough constitution; he was a good hunter and well versed in the ways of ice and snow. He incurred little risk of accident and none of starvation in a day when game was not scarce. His end, however, was never known. He faded away and no one knew what came of him. Perhaps the bears got him one winter or perhaps he tired of the life and shipped home to Norway on a wandering sealer and gave no name or indication of his identity.

A beachcomber of a different type was W., a giant of a man, a great talker with a roaring laugh and an undisguised appetite for life. He was of Danish origin. A Dutch mining company first brought him to Spitsbergen and for two years he was in their employ mainly on outlying estates where the Dutch had little more than a foothold. W. was a good custodian of his employers' rights; trespassers walked warily and soon left. In the winters he lived in a comfortable log house in Grønfjorden, a rough and ready life with ample food and the solace of female companionship. "Gin valley" as the Dutch headquarters at Barentsburg was popularly called, suited W. and he was known in every mining camp. One of his properties was a motor launch which was a good seagoing vessel in its hull but a little ancient in its engine. In W.'s hands it made many journeys in spite of frequently breaking down. One morning about 2 a.m.—for time of day counts little in the endless daylight—W. picked up me and two others in his launch and was to take us to Adventfjorden. Of course the launch broke down and we drifted with the tidal current, W. working at the engine and his passengers plying sweeps to keep the vessel clear of reefs. Hour after hour went by; we breakfasted off a chunk of poor Norwegian cheese, surely the world's worst cheese, and neat whisky, we had no water and no bread but tobacco was plentiful. The engine refused to function and then luck came our way. A hunting sloop with motor engine gave us a tow, pulling us happily off a dangerous coast with promise of a safe end to our voyage. Then suddenly a shout of triumph from W. announced the revival of the motor. We cast off the tow rope, with some doubt, and went our way. As he tightened the final nut W. threw me his wrench with a laugh. "Keep it as a souvenir: I've plenty and it may serve you again." Time proved his hope to be justified. And his launch earned W. a useful income. When the Dutch sold out to Soviet owners, W. stayed on in Spitsbergen. The life suited him and he fitted in on the verge of human society somewhat better than in its midst. For a few years he was up north at the Kongsfjorden coal mines, which were the base of several flying ventures over Arctic seas. W. was at the start of all, and sprang into prominence after the disaster of Nobile's *Italia*. He led an autumn sledge journey along the north of the country in a search for survivors, and, though he found none, W. showed his amazing toughness and endurance on this forced march. And then the picture fades. W. recedes into the background but lived on in Spitsbergen for several years, making a living in one way or another and always enjoying his chosen way of life.

Among the trappers of recent years there were several who almost became colonists though most were only winter visitors. Twenty years ago a half-ruined hut on Tempelfjorden at the mouth of Sassendalen, called Bruce hut

for no reason whatever, housed Count C. and another Russian. Exiles from Soviet Russia, these two aristocrats of the old regime lived for several years in a hut some 12 ft. square. Their food was mainly reindeer and bread; whatever else they wanted the nearest mining settlement supplied in small quantities. Living was precarious, for furs were scarce and competition was keen, but never did these two Russians fail to offer the most courteous, albeit humble, hospitality to any wayfarer. They professed to like the life but always looked forward to a change in Russian politics which would admit their returning to their own country. That emancipation never came but Count C. and his companion left Spitsbergen for a destination unknown.

Another much humbler settler was a Norwegian trapper who, with his wife, lived at least rent- and rate-free, in Spitsbergen. The pair had no fixed abode but chose any suitable abandoned hut with little regard to ownership or maintenance. They were a primitive pair, not unkindly nor greedy but lacking any ambition to improve or brighten their living quarters or to rise much above subsistence level. For a time they seem to have lived in the six-roomed capacious Swedish house at Kapp Thorsden—at one time a palatial house but long neglected and not enhanced by its hard-by grave of seventeen hunters who had died of scurvy. Johann, or whatever his name may have been, had a grim problem to face one winter. His wife was taken seriously ill; the only hope was to see a doctor and there was one across the fjord at Longyearbyen—but the journey entailed twelve miles of drifting pack ice and the only boat available was a small and crazy pram—useless for the task. So Johann decided to go by land round the head of Isfjorden a fifty-mile journey at the least. He had a sledge in reasonable repair but no dogs. He lashed his wife to the sledge wrapped up in all the skins he had, and set out along the coast. Fortunately the ice in Billefjorden held and they crossed without mishap. Then the way was dangerous over Gipsvika as far as Bjonahamna where they found a hunter's hut with two men and rested a few hours. Then onward up Sassenfjorden which could not be crossed and over the high rugged Von Postbreen and westwards to Sassendalen over the frozen river and round the coast to Adventfjorden—a long, circuitous route, beset with ups and downs and many stretches of difficult and dangerous ice, but they reached help in time and the operation for appendicitis was successful.

Another Norwegian trapper who left his trace in Spitsbergen was Nois. I never saw him but in many huts I have found his name below a message on the wall recording a visit and sometimes a note of stores or equipment which he had "borrowed"....

When prospectors for coal, iron and oil were numerous every summer, a few Norwegian hawkers did some trade in eider eggs, ducks, geese and venison. They were 'left over' from the horde of winter trappers, failures perhaps and so with no incentive to return to Norway in summer. They would sell eggs or game for tea, milk or other stores and never refused a noggin of gin or whisky to seal the bargain. The more prosperous did their transactions for krone.

Among all the Spitsbergen characters none was so widely known as the "Arctic Monkey", and none made so great a success of his various enter-

prises. His ancestors certainly came from eastern Europe and report had it that his original name was Levinski but as his father moved westwards Levinski became Levin and Levin became Lewin, and the "Monkey" and his brother claimed to be Norwegian subjects. The trio of father and two sons "discovered" Spitsbergen when it was still a No Man's Land and mining claims were being freely made and freely jumped. Old Levin may have visited Spitsbergen but was generally to be seen in Tromsö where his astrakhan collar, moth-eaten fur coat, and weathered bowler hat were familiar. The elder brother was over-shadowed by the younger of the trio, the "Monkey". He was a weedy youth, shabbily attired in clothes that looked second-hand with a perpetually dirty collar. He always appeared to be, but never was, in financial deep water. He had an unquenchable thirst for whisky of any kind, good or bad, it was all the same to him. His amorous escapades were numerous but never costly. He was well versed in the shady ways of life. But the "Monkey" was no brainless waster. He was a man of unusual intelligence, a well-read man, devoted to real music and with a keen sense of beauty in nature.

The "Monkey" belied his effete appearance. He had great powers of endurance, an indifference to cold and a cheerful disposition in all discomfort. There were few better Spitsbergen travellers and he knew the country well. In midwinter he would cross on ski from one coal mine to another, from Grønfjorden to Adventfjorden, without any companion. If wind and snow blocked the way, the "Monkey" curled up in a snowdrift to await better conditions. He was never dismayed; obstacles encouraged him.

He spent several winters and many summers in and around Grønfjorden where he maintained sketchy claims to land and spoke of various ores but he never engaged in more than prospecting. He had no small knowledge of mining and minerals but the "Monkey" was a speculator not a miner. It was he who described Spitsbergen as "The only country where you can sell land that doesn't belong to you—and get away with it!" The "Monkey" certainly made money out of Spitsbergen and not least in the deal by which the Netherlands company acquired the mine in Grønfjorden in 1919.

Tough as the "Monkey" was, the sea was his terror. He was universally seasick; no experience cured him. Once I travelled from Harstad to Adventfjorden with him. I had a berth but the "Monkey" preferred to save money by taking a deck passage on the cargo boat that conveyed us. He said he was sure to be miserable and refused to pay for his misery. With his luggage, a tawdry suitcase, a paper bag full of bananas and a bottle of *ersatz* whisky, he went aboard and soon after sailing disappeared in a snug corner among a deck cargo of bales and barrels. For three days he was invisible; then as we entered the quiet waters of Isfjorden, he emerged dishevelled, unshaven and dirtier than usual. Generously he offered to share what remained of the bananas and whisky, turned his collar inside out, folded his tattered raincoat over his arm and was ready to step ashore. No doubt Levin has passed on to other fields where his enterprise will find the rewards he seeks; Spitsbergen has lost a picturesque character and a striking personality. What he did with his gains I never knew; certainly he never sunk his profits in Spitsbergen. Once when he told me of a

good deal, I asked him if he celebrated the event. "Yes, ve did that: my father he buy a new fur coat; my brodder he just throw up his hat and say 'Hurray'." "And what did you do, Levin?" I asked. "Vell, I got a bottle of viskey."

Very different from these humble folk was the man who for many years was the virtual king of Spitsbergen, the autocrat who was manager of the great Norwegian coal mine in Adventfjorden. Karl Bay led a coal-prospecting expedition to Kongsfjorden in 1911 but this was probably not his first visit. On that occasion he had with him a German mining engineer but his company was Norwegian. In succeeding years Bay was in Kongsfjorden until in 1916 the coal field changed hands and Bay transferred his services to the Norwegian company that had bought the American coal mine in Adventfjorden. There his tireless energy found ample scope and the mine and settlement were extended and export grew rapidly. Bay had a genial manner which hid a firm and unyielding will. He was by nature an autocrat and his suavity was a cloak. He could be kindly and even generous but always the interests of his company came first. Claim-jumpers on the Norwegian estates had short shrift and all the shorter if they had no strong backing. Bay respected power and had little sympathy for weakness. Three novices to Spitsbergen who proclaimed themselves as representatives of an English syndicate seeking oil inadvisedly proposed to bore in Adventfjorden. Karl Bay was at once on the spot with an armed escort; the three startled men took Bay's "advice" and left.

Bay had his social side; he enjoyed life and good living. I recall many delightful meals in his company in Longyearbyen. His death from appendicitis was a loss to Norwegian interests in Spitsbergen—for to all intents and purposes while Bay lived he ruled Spitsbergen.

UNITED STATES RESEARCH AT DRIFTING STATIONS IN THE ARCTIC OCEAN

BY IRENE BROWNE COTTELL*

[*MS. received 7 April 1960.*]

Project "Ice Skate" was initiated in 1957 to establish and support the United States drifting research stations in the Arctic Ocean, "Alpha", and "Bravo" and later the "Alpha" replacement, "Charlie". The purpose of the project was to provide facilities for research in geophysical phenomena as prescribed in the Arctic Ocean Study Program formulated by the United States National Committee for the International Geophysical Year, and continued under the International Geophysical Co-operation Program.

Drifting station "Alpha". Station "Alpha" was set up on 5 April 1957 in lat. 79° N., long. 159° W., directly on an ice floe in the Arctic Ocean. The area of the floe was about 10 sq.km. but repeated ice cracks necessitated moving the camp site three times during the nineteen months of occupation, and finally abandoning it on 6 November 1958. The scientific programme began in June 1957 and, between then and November 1958, the station drifted over 1700 nautical miles, averaging about 3·4 nautical miles per day.

Drifting station "Bravo". Station "Bravo" is on a remnant of ice shelf known as "Fletcher's Ice Island," or "T-3." Prior to the "Ice Skate" operation, it was occupied continuously between March 1952 and May 1954 as a weather and geophysical research station by United States Air Force personnel and civilian scientists. A second occupation during the spring and summer of 1955 was undertaken to continue the geophysical investigations.[1]

Since 1947 the ice island, which was in lat. 82° 46′ N., long. 99° 33′ W. when the present occupation began, has moved through one and a quarter cycles of the large orbit of clockwise ice circulation north of Alaska. The shallowest depth encountered has been 197 m., in the region of Prince Patrick Island.

Drifting station "Charlie". Scientific studies began in June 1959 in the region of lat. 75° N., long. 162° W. and on a floe measuring 80 sq.km. and averaging 3 m. in thickness.

The movements of this station are unlike the pattern of the other ice stations that have drifted in the region. Instead of a northerly course, the total drift vector was westerly, in the direction of Novosiberskiye Ostrova, while the rate of drift averaged about 4·6 nautical miles a day.

Owing to storm damage this station was evacuated in January 1960.

Logistic support. The United States Air Force is responsible for the establishment and maintenance of the Arctic Ocean stations in support of Project "Ice Skate". The initial facilities at "Alpha" and "T-3" were planned and

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implemented by the Alaskan Air Command and the Northeast Air Command, respectively. Support and maintenance of the "T-3" facility are at present carried out by the Alaskan Air Command.

Scientific studies at the United States drifting stations

Position determinations. The geographic co-ordinates of stations "Alpha", "Bravo" and "Charlie" were determined by observations of the sun, moon or stars using precision theodolites or transits. Daily astronomical fixes were attempted, but frequent poor visibility conditions precluded attainment of a daily schedule. Computed positions are accurate to within one half of a nautical mile for the majority of readings obtained at all stations.

Meteorological observations. The meteorological programme consists of surface synoptic observations, upper air data, and selected studies such as solar radiation, carbon dioxide, ozone and snow crystals.

In the synoptic programme, observations of the sky cover, ceiling, visibility, wind, pressure, temperature and dewpoint are made every three hours. Wind, pressure and temperature are recorded continuously.

Radiosondes, to heights of 20 to 35 km., have measured the upper air wind, humidity and temperature twice daily at stations "Alpha" and "Charlie". Pibal ascents provided additional data. Prior to January 1960, upper air data on "T-3" were limited to twice daily pibal probes and occasional wire-sonde measurements as the proximity of the island to upper air stations in Canada and Alaska reduced the need for such data. Upon evacuation of station "Charlie", the upper air equipment was transferred to "T-3", where it is now in continuous operation.

Solar radiation instruments installed at the stations have included up-and-down facing "Kipp" solarimeters, up-and-down facing "Eppley" horizontal incidence pyrheliometers, normal incidence pyrheliometer, up-and-down facing illuminometers, total hemispheric and net radiometers, a sky brightness meter and sunshine recorder.

Upper atmosphere physics. A patrol spectograph and all-sky camera were installed at station "Alpha" to record aurorae and airglow, and an all-sky camera was also set up on "T-3". Both instruments are operated during the winter season. Records are sent to the data centre at the University of Alaska.

A C-2 vertical incidence ionospheric sounding instrument, using a sweep frequency pulse sounder, was in operation on "T-3" during the period 1957 to 1959. Continuous measurements in the form of ionograms of virtual heights and critical frequencies were obtained to study the nature and variations of the electron density.

Signals from Sputnik satellites were monitored on "T-3" during autumn 1957, when the position of the island was ideal for reception far beyond the normal horizon.

Heat budget studies. A full scale study of the thermal regime in the Arctic Ocean, and particularly of the heat exchange factors and interactions between the air–ice interface and ice–ocean interface, was undertaken at "Alpha" and

"Charlie" stations, and to a somewhat lesser extent on "T-3". The physical contributions of the atmosphere, ice and ocean to the formation and perpetuation of the Arctic ice cover and their relation to the meteorology and climatology of the region were studied.

Work on "Alpha" and "Charlie" consisted of measurements of the heat transfer across the ice–ocean boundary, the rate of accretion on the underside of the ice, temperature readings in the ice, accumulation and ablation of surface snow and ice, melt season effects, vertical temperature and wind gradient structures in the near surface layer of the atmosphere, incoming and reflected solar radiation, and incoming and outgoing total and shortwave radiation.[2,3] On "T-3" work is concentrated on the determination of surface interactions and variations and on the ice thermal structure. The great thickness of the ice island has restricted underside ice considerations to measuring the effects of melt water drainage in the surface waters. The network of ablation stakes set into the ice island in 1952 has been expanded to include coverage of the major ice formations and representative areas. The net surface ablation of the island in 1958 and 1959 in lower latitudes has amounted to about 1 m. a year.

Ice physics and petrofabrics. Numerous ring and beam tests were conducted at "Alpha" to find the tensile strength of sea ice in various stages of growth and deterioration. The ice floe was subjected to load tests applied in a wide variety of conditions, and compressive strength was measured on numerous samples. Sonic and in-place beam tests were used to study dynamic and elastic properties. Numerous salinity and density determinations were made. Special seismic waves, artificially generated in the ice, provided additional information concerning such factors as elastic constants and layering.

Ice cores obtained at the drift stations were subjected to detailed examinations.[4] Observations of colour, thickness, profile stratifications, brine content, origin, formation and age, and variability of ice characteristics were made. Petrological analysis included the crystal structure, axis orientation and boundary layer characteristics. Layering of ice indicated seasonal cycles in the crystal structure and salinity, which in ice from "Alpha" have been identified for the past eight years.

Much work had already been accomplished on "T-3" from 1952 to 1955 in relating island structure, organic and biological collections to the origin and history.[5] Emphasis during the present occupation has been placed upon a study of the surface morphology, drainage system, lake formations and melt season effects; identification of ice types, and their origin, development and relation to the Ellesmere Ice Shelf; ice island crystal structure and the thermal regime.[6] Seismic and electromagnetic surveys were conducted across a line on the ice island and in the surrounding ice to determine thicknesses.

Gravity. The gravity values were read at "Alpha" and "Bravo" stations at least once daily in order to obtain corollary information on bottom topography. A "North American" gravity meter is installed on "T-3" and a "Frost" gravity meter was used at "Alpha". Station "Charlie" was closed before a gravity meter designed particularly for Arctic Ocean use could be

installed. In addition to the routine gravity observations, a study of continuously recorded gravity measurements has recently been initiated on "T-3" to investigate long period oscillations.

Magnetic studies. The magnetic declinations at each station were determined daily. An "Askania" variograph provided continuous recordings of the relative changes in the D, Z and H components of the magnetic field at both "Alpha" and "Charlie". Absolute measurements of the horizontal intensity at "Alpha" were obtained using a deflector magnet. The magnetic programme at "Charlie" also included measurements of the total field intensity by the proton precession method. On "T-3" magnetic measurements have varied with the availability of equipment. For brief periods since 1957, "Bendix" and "Ruska" magnetometers have been in use and a three-component "Askania" variograph, a dip circle and proton magnetometer were also operating at various times on the island.

Oceanographic studies. The programme included the occupation of hydrographic stations at standard ocean depths. Measurements of temperature, salinity, dissolved oxygen content, phosphate, nitrate and pH concentrations are obtained.[7,8,9,10] A bathythermograph and a thermistor line sensitive to water temperature within 0·01° C. provided additional temperature profiles.

Ice movement studies are in progress. Station surface wind observations, regional contours of the surface isobars and the surface water movements are correlated with the drift pattern to determine the nature and causes of drift. Detailed profiles of the ocean currents beneath station "Alpha" have been obtained and the results correspond closely to the Ekman spiral. Preliminary results of the drift studies have been published.[11]

Biological studies of primary productivity in the Arctic Ocean were made at station "Alpha" and "T-3". The photosynthesis effects, chlorophyll concentration, light penetration through the ice and nutrient concentrations were investigated.[4,12,13] An underwater study of the amount of solar radiation passing through the ice cover was conducted by skin divers on station "Alpha".

Submarine geophysics and geology. Arctic Ocean depths and the sub-bottom configuration were explored by seismic reflection methods at each station. Electrical measurements of the bottom resistivity were also undertaken at "T-3".

Results at "Alpha" revealed the existence of a prominent submarine rise, termed the "Alpha rise", which is parallel to the Lomonosov Ridge. In the central portion of this feature, in lat. 85° 03′ N., long. 171° W., the minimum depth recorded was 1426 m., and depths increase to over 3000 m. at the lowest part of the rise.[14,15]

Since the outset of the IGY programme, "T-3" has been travelling near the edge of the continental shelf, fringing the deeper waters of the Arctic Ocean.[16]

Station "Charlie" was carried over the Chukchi Rise. A precision depth recorder has been used to supplement the seismic reflexion programme, and because of the nature of the drift, the features of the Chukchi Rise could be investigated extensively. Depths were found to be shallow, between 256 and

463 m., and the feature might more properly be termed a continental peninsula, as an extension of the continental shelf, rather than a rise or seamount.[17]

Bathymetric data obtained at the drifting stations were made available for navigational use during the pioneer voyages of the nuclear submarines under the ice.

Seismic refraction methods are used to provide descriptive data on the sediments beneath the Arctic Ocean floor. Photographs of the sea floor, and numerous cores and dredgings, have been obtained to reconstruct the geological and climatological history.[18] The topography and layering of the ocean floor suggest that the Arctic Ocean is a normal ocean basin similar in its sea floor to the Atlantic Ocean.

Participating organizations in United States drifting station programmes

The United States National Committee for the IGY arranged through various organizations to provide the diverse technical skills necessary in the conduct of the drifting station programmes. The United States Weather Bureau directed the meteorological stations. The micro-climatological and sea ice petrofabric studies were conducted by the University of Washington's Department of Meteorology and Climatology. The Snow, Ice and Permafrost Research Establishment was responsible for the study of sea ice physics and mechanics. The ionospheric physics programme was supervised by the United States Army Signal Radio Propagation Agency. The Geophysics Research Directorate, Air Force Cambridge Research Center, directed the aurora and airglow programme and the investigations in geophysics, ice island characteristics, oceanography and submarine geology. The Lamont Geological Observatory of Columbia University conducted "Alpha" and "Charlie" studies in marine geophysics and submarine geology. The Geophysics Branch of the United States Geological Survey handled the equivalent programme on "T-3". Dartmouth College undertook the "T-3" surface morphology studies. The Arctic Institute of North America was responsible for marine biological studies on "Alpha" and, through arrangement with the Institute of Low Temperature Science, Hokkaido University, Japan, for oceanographic and ice crystallographic studies on "T-3". Oceanographic observations were also made by the Woods Hole Oceanographic Institution, the United States Navy Hydrographic Office and the Fisheries Research Board, Canada. Underwater acoustic measurements were undertaken by the United States Navy Underwater Sound Laboratory.

At the end of the IGY, most of the participants continued their respective research programmes in co-operation with the United States Navy Office of Naval Research or the United States Air Force Geophysics Research Directorate. In addition to the list of investigators there were marine biologists from the University of Southern California and a geophysicist from the University of Alaska working on earth current studies. The University of Washington expanded previous investigations to include oceanographic investigations on "Charlie".

Future United States research in the Arctic Ocean

Consideration is being given to the establishment of a new ice floe research station, "Delta", or, alternatively, short-term satellite stations to supplement work on "T-3". The "T-3" programme, as summarized above, will be intensified and expanded to attain the maximum in scientific coverage and output, and the number of scientific personnel has already increased to sixteen under the administration of the Geophysics Research Directorate. Light aircraft, the Cessna 180, attached to the Arctic Research Laboratory at Point Barrow, are expected to assist in special "T-3" research programmes, such as seismic refraction profiles.

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FIELD WORK

BIOLOGICAL WORK ON PRINCE OF WALES ISLAND, 1958

[Summarized from a note in the *Arctic Circular*, Vol. 12, No. 3, 1959, p. 40–43.]

A party, jointly sponsored by the National Museum of Canada and the Canadian Wildlife Service and led by T. H. Manning, carried out a biological investigation of Prince of Wales Island during the summer of 1958. Other members were Mr and Mrs Andrew Macpherson.

The selection of Prince of Wales Island was made because of its position in the middle of the largest area of biologically unknown territory in the Canadian Arctic. It also commands the shortest water-crossing of the Parry Channel which elsewhere forms an effective barrier to the north–south dispersal of many birds and mammals. The objects of the expedition were to collect specimen samples of the bird and mammal populations for taxonomic studies, to collect distributional data, to assess the size of bird and animal populations and the potentialities of the island for Eskimo settlement. In addition, collections of fish otoliths and scales were made for the Fisheries Research Board, and of plants for the National Herbarium. Reports on these activities are not yet published.

CANADIAN POLAR CONTINENTAL SHELF PROJECT, 1959

[Summarized from an article by E. F. Roots in the *Arctic Circular*, Vol. 12, No. 3, 1959, p. 32–38.]

The Canadian Polar Continental Shelf Project has been organized by the Department of Mines and Technical Surveys to carry out oceanographic, hydrographic, geophysical, geological and related studies on the continental shelf underlying the Arctic Ocean adjacent to the Canadian Arctic archipelago, together with studies on the islands where relevant, and in the straits and sounds between the islands. There is no fixed date for the completion of the project, to which a number of government departments and agencies are contributing, and it is expected that scientific and survey work will continue for some years.

During the first field season there were two separate field parties; one based at Isachsen, Ellef Ringnes Island, on the edge of the oceanic part of the continental shelf, and the other operating from CGS *Labrador* in southern Foxe Basin and western Hudson Strait.

The Isachsen party, in which twenty-two men took part for different periods, worked in the area from mid-March until mid-October. Their object was to provide a surveyed base line in preparation for the first full season of survey and research in 1960, and to test equipment and methods. The first area to be worked is a block, roughly 200 miles long and extending 250 miles out to sea, lying to the north-west of Meighen, Ellef Ringnes and Borden Islands. This will be followed by blocks to the south-west and north-east. During 1959 most of the time was spent in fixing the position of stations and testing electronic positioning devices. Three base-lines were run from Isachsen by means of tellurometer and theodolite; one across Prince Gustaf Adolf Sea to Borden Island, the second to Borden Island by way of Amund Ringnes Island and the Fay Islands, and the third across north-western Ellef Ringnes Island to Cape Isachsen and out over the Arctic Ocean. These lines fix the exact positions of the three stations to be used as the main survey bases during 1960. The sites of these stations were also prepared. Master and slave Decca electronic positioning stations were erected on a 22-mile base line between Isachsen and Noice

Peninsula, western Ellef Ringnes Island. Results collected during field tests indicate that it will be quite possible to erect an electronic positioning system which will give acceptable accuracy up to at least 250 miles. Hydrographic soundings were made at intervals along the main base lines; regular oceanographic measurements and samples were taken at all standard depths, together with bathythermograph casts and current measurements (the last of questionable validity). Tidal records were kept and a study made of the effects of temperature, wind and other possible factors on tides in ice-covered waters. More than 80 gravity measurements were taken with a temperature-compensated specially damped Worden gravimeter on both land and sea ice, including a traverse across a typical gypsum piercement dome. A gravity and magnetic traverse of the Meighen Island ice cap was completed, also magnetic surveys of parts of Meighen and Ellef Ringnes Islands. Geological work included taking grab samples and cores from the floor of Prince Gustaf Adolph Sea and the ocean near Cape Isachsen; studies of stratigraphy of northern Ellef Ringnes Island; and the collection of specimens for study of remnant magnetism.

A start was made on the glaciological programme, which should run for at least three years; work was carried out on the Meighen Island ice cap, on small glaciers near Isachsen, and on sea ice in the vicinity of Ellef Ringnes Island.

The party included personnel from the Department of Mines and Technical Surveys, Computing Devices of Canada Ltd., and McMurray Air Services, Ltd., with E. F. Roots as co-ordinator. It was supported by a Beaver and an Otter aircraft, both ski-equipped, and latterly by a second Otter replacing the Beaver. Over 400 landings were made by the Otter on unprepared runways on sea ice and bare ground, while transporting field parties. Land transport was by means of motor toboggans and, less successfully, by an amphibious Snowmobile.

The work of the second party, based on the *Labrador*, lasted from early September until mid-October and was carried out after the completion of the vessel's regular convoy and icebreaking programme in eastern Arctic waters. It consisted of a series of planned traverses in the region of Foxe Basin, western Hudson Strait and north-eastern Hudson Bay, during which normal oceanographical and marine geological observations were made and samples taken. Eighty-five complete oceanographical stations were occupied during 1300 miles of traverse. The senior oceanographer of the party was A. E. Collin of the Polar Continental Shelf Project and other members came from the Great Lakes Geophysical Group and the Atlantic Oceanographic Group.

ARCTIC UNIT OF FISHERIES RESEARCH BOARD OF CANADA: FIELD ACTIVITIES IN 1959

[Summarized from *Annual Report of Fisheries Research Board of Canada, 1958–1959*, Ottawa, 1959, p. 111–15.]

Fisheries investigations

Fish studies continued to concentrate on general surveys for basic information on abundance and distribution. Surveys were carried out of the Anderson River and nearby lakes, and of the streams and lakes of Banks Island. A special study was made of the stocks of Arctic Char (*Salvelinus alpinus*) in relation to the small commercial fishery on the Sylvia Grinnell River, Frobisher Bay, begun in 1958 by the Department of Northern Affairs and National Resources. Some 40,000 lb. of this species were taken from the river during 1958. The picture of the life cycle of Arctic Char is still incomplete, but three stages of maturity, particularly evident in females, suggest that spawning occurs only every third year. This confirms conclusions based on an investigation made in 1950. Analysis of the data collected indicated that a rate of fishing mortality of about 20 per cent of the stock, producing a sustained catch of

about 45,000 lb. annually, is possible. This relatively low sustained yield indicated that any development of organized char fishing in the Arctic should take the form of numbers of small efforts spread over a number of years.

Samples of fish were taken on several lakes, including Sylvia Grinnell Lake, in the Frobisher Bay area; some with access to the sea, and some landlocked. These disclosed two distinct main types of Arctic Char: large anadromous fish maturing at about 13 years of age, and smaller "landlocked" fish maturing at 6 to 7 years of age. The former type carried few or no parasites, while the latter showed heavy parasitism. Winter sampling of Sylvia Grinnell Lake suggests that spawning takes place no later than September or October in both types of fish. Investigations are producing widely different ecological types even within the same body of water, and strengthen the view that the Arctic Char is a polytypic species.

Arctic Char were also collected from Lake Hazen, Ellesmere Island, the most northerly water yet studied, and about 540 specimens were examined. Primary production in the lake, though very low, began in mid-June before the beginning of the melt season and under 5 ft. of ice and 1 ft. of snow. Collections of zooplankton were made for laboratory analysis, also of the chironomid larvae which form almost all of the benthos. Two bottom cores from an adjacent lake, which are considered to incorporate the whole sedimentary history of the lake, were collected for biostratigraphic analysis.

Collections of true herring (*Clupea*) were made at Tuktoyaktuk, Mackenzie District, to support a detailed taxonomic study and to compare with Atlantic and Pacific forms. A few true (Pacific) salmon, taken regularly in the nearby area of the Mackenzie River, show that the migration for spawning occurs at about the same time as on the Pacific coast.

Marine mammal investigations

Harp seal. The main activity consisted of air photographic survey of whelping Harp Seals (*Phoca groenlandica*) in the Gulf of St Lawrence and off the east coast of Labrador and Newfoundland. This survey was a continuation of others made during 1950, 1951 and 1955, and was another attempt to achieve complete photographic coverage for the entire east coast of Canada. In the Newfoundland area an approximate figure of 425,000 for pup production was tentatively arrived at, compared with that of 430,000 estimated for 1950 and 1951. At the time of the photographic survey, whelping was not completed in the Gulf of St Lawrence area. Continued check on the age composition of stocks confirms that a kill of the order of about 250,000 young seals in a year leads to a low survival rate, compared with years of catches of about 180,000 or less.

Harbour seal. Data now collected proves that the Harbour Seal (*Phoca vitulina*) is a permanent resident in the Arctic under suitable conditions.

Walrus. Walrus (*Odobenus rosmarus*) samples taken from Foxe Basin, Resolute and Southampton Island suggested that the populations in these areas are not being over-exploited.

Biological oceanography

Owing to uncertain ice conditions M.V. *Calanus* sailed directly from Rowley Island to Moosonee, James Bay, and no work was carried out in Foxe Basin during the season. However, investigations made along the east coast of Hudson Bay, between Hudson Strait and James Bay, indicated that the low salinity is a limiting factor for plankton and benthos in south-eastern Hudson Bay.

GLACIOLOGICAL AND BOTANICAL STUDIES IN NORTHERN ELLESMERE ISLAND, 1959

[Summarized from a note by J. M. Powell and R. B. Sagar in *Arctic*, Vol. 12, No. 4, 1959, p. 244–45.]

J. M. Powell and R. B. Sagar spent from 18 May to 18 August 1959 in the region of the Gilman Glacier, in lat. 82° 08′ N., long. 70° 57′ W., in north-eastern Ellesmere Island. Their work was mainly complementary to the glaciological and botanical work of Operation "Hazen", 1957–58.

A camp was established near the snout of the glacier and the programme began by measuring ablation and accumulation data for 1958 from the stakes set up in 1957–58. Later in the season additional ablation stakes were set up in the face of the snout. Between 13 June and 5 August systematic synoptic and micro-meteorological readings were taken; also investigations of plant ecology and plant communities in specific areas of the Lake Hazen–Gilman Glacier region. Less detailed meteorological observations were made after this period, when heavy and bulky equipment had been removed by helicopter to USCGS *Westwind*. G. F. Hattersley-Smith joined the party for this stage of the expedition and the party re-visited all the glacier stations in order to collect ablation data. Late-summer seed and plant collections were also made. The party returned to Lake Hazen and were picked up by a RCAF aircraft on 24 August.

A preliminary examination of glaciological data showed that accumulation of snow had been approximately the same in 1957, 1958 and 1959. The amount of ablation had decreased progressively from 1957, while the 1959 ablation season had been shorter and probably cooler than in the previous years. The present morphology of the glacier terminus indicates that a slight re-advance of the ice during a complete year may be occurring. A close relationship was observed between the amount of ablation over the lower part of the glacier and the solar radiation income.

Botanical studies confirmed previously noted features, and include a number of holarctic range extensions.

SOVIET DRIFTING STATIONS IN THE ARCTIC OCEAN, 1959–60

[From *Vodnyy Transport* [*Water Transport*], 15 and 26 September 1959, 9 February, 22 March and 30 April 1960; Moscow Radio 18 September 1959, 15 April 1960.]

After the annual relief in the spring of 1959, SP-6, the ice island station in the fourth year of its existence, drifted towards the Greenland Sea, and SP-8, the new station, drifted in the area about midway between Bering Strait and the Pole. As was expected, SP-6 soon reached the point at which it was about to drift out of the Arctic Ocean in the Greenland current, and the station was accordingly evacuated in early September 1959. For this purpose nine flights were made from Zemlya Frantsa Iosifa to the site of the station in lat. 83° 6′ N., long. 3° 56′ E. A hut with food and fuel in it was left on the ice, both for shipwrecked mariners and in order to identify the piece of ice as it drifts southwards. While manned, the station drifted some 5800 miles, while the direct line from start to finish was 1600 miles.

SP-8 drifted rather slowly in a north-westerly direction. In the summer the melting and cracking of the floes in its vicinity prevented any aircraft from landing there until September.

The annual high latitude air expedition, which was responsible for relief, was called "Sever-12" and was again led by M. M. Nikitin. It made its base at Tiksi. SP-8 was relieved during the first half of March by a new team under N. I. Blinov,

the station then being some 450 miles north of Ostrov Vrangelya. A turbo-prop AN-10 aircraft was used to bring in freight—the first occasion on which such an aircraft has landed on sea ice. A new station, SP-9, was set up in lat. 77° 23′ N., long. 163° E., about 500 miles north-east of Novosibirskiye Ostrova, in mid-April. The floe on which the camp is sited was chosen after a long search, and measures 3 by 1·8 km. by 2 to 3 m. thick. A party under V. A. Shamont'yev and 100 tons of stores were flown in, and regular observations were started at the end of April.

UNDER-ICE WINTER CRUISE IN THE ARCTIC BASIN: U.S.S. *SARGO*

[Summarized from United States Navy press releases.]

The United States nuclear-powered submarine, USS *Sargo*, Lieut.-Commander J. H. Nicholson, carried out a winter cruise of thirty-one days under the ice of the Arctic basin during January–February 1960.

Accompanied by USS *Staten Island*, *Sargo* approached from the Bering Sea and submerged near St Laurence Island, off the west coast of Alaska, on 26 January, reaching the North Pole on 9 February after a voyage of 2744 miles (4390 km.). On her return south, the submarine re-surfaced near the same place. During the complete under-water cruise of about 6000 miles (9,600 km.) *Sargo* surfaced 20 times, at least twice through ice 3 ft. (1 m.) thick. Improved sonar gear facilitated the passage of the submarine through shallow areas in the Bering and Chukchi Seas.

Measurements of ice thickness, water temperature, salinity and gravity were made throughout the cruise.

ITALIAN EXPEDITION TO BOUVETØYA, 1959

[From information supplied by Professor S. Zavatti.]

During March 1959 Professor S. Zavatti, meteorologist, and G. Costanzo, photographer, made a reconnaissance voyage to Bouvetøya with the object of discovering a site on the island suitable for a scientific station.

From Cape Town the party travelled in a fishing vessel, CM IV. The island was enveloped in fog during most of the visit. They spent 22 and 23 March on Larsøya and, on the 24th, landed at a small bay south of Kapp Circoncision. No sea ice was observed and the mean temperature was 3° C.

The party was unable to discover a site suitable for a scientific station and left the island on 25 March.

FRENCH ACTIVITIES IN ANTARCTICA, 1959–60

[Summarized from *Bulletin d'Information*, issued by Expéditions Polaires Françaises, 3 July 1959, 4 January 1960, and 3 April 1960.]

Routine scientific observations were carried out during the winter of 1959, with only one journey of any length which consisted of a visit to "B 3", between 25 September and 12 October, to carry out glaciological observations and to recover the Sno-cat left there in 1957.

Norsel reached Pointe Géologie on 2 January 1960 carrying the twelve members of the 10th French Antarctic Expedition under Alfred Faure, a summer party of six led by Professor Bellair, a helicopter party of three, and MM. Ponchelet, Rolland and Best.

The ship was unloaded by the 22nd and sailed westwards along the coast to enable members of the summer party to carry out their scientific programmes. These were: hydrography and survey under R. Lefas; geology under Professor Bellair; and

radioactive studies under B. Parlier. Rough weather and storms forced the ship to return on the 28th and, until her departure for France on 2 February, scientific work was carried out in the vicinity of the station.

The Djinn helicopter was again used for unloading the ship, carrying 135 tons in 105 flights during 54 flying hours. The aircraft was also used to survey Glacier de l'Astrolabe and the plateau in the neighbourhood of Pointe Géologie. During the summer a hut was erected and equipped for the study of radioactive fall-out in Terre Adélie, and a start made on a number of new buildings and installations to be completed during the winter.

NEW ZEALAND ACTIVITIES IN THE ANTARCTIC, 1959–60

[Summarized from *Antarctic*, Vol. 2, No. 4, 1959, and No. 5, 1960.]

New Zealand Geological and Survey Expedition, 1959–60

The main New Zealand activity during the 1959–60 season was a geological and topographical survey south of McMurdo Sound, particularly the area between Barne Inlet and the Beardmore Glacier. There were two parties. One, with three dog teams, consisted of B. M. Gunn (leader), P. J. Hunt and J. Matterson, surveyors, and R. I. Walcott, geologist. The second, using two Sno-cats bought from the Commonwealth Trans-Antarctic Expedition, was led by M. Robb and included T. Couzens, driver, D. R. Goldschmidt, surveyor, and J. H. Lowery, geologist.

The parties, leaving "Scott base" on 2 and 7 November 1959, reached the neighbourhood of Cape Selbourne by the 17th, but were prevented from attaining the Cape itself by large crevasses, and held up by bad weather. Two days later, Gunn, Couzens and Lowery set out in one of the Sno-cats to make a reconnaissance towards the coast. Half a mile from the camp the Sno-cat disappeared down a 100 ft. crevasse, Couzens was killed, while the other two were severely injured and unable to communicate with the remainder of the party; they were discovered next morning, some eighteen hours after the accident. They were flown to "NAF McMurdo" by United States helicopter and thence to New Zealand.

The party was immediately re-organized and transported, by United States aircraft, to a small glacier south of Shackleton Inlet. Their object was a reconnaissance survey of the 40-mile coastal strip between the Nimrod and Beardmore Glaciers, abutting the area surveyed during the Commonwealth Trans-Antarctic Expedition by J. H. Miller and G. W. Marsh.[1] They moved up the glacier and reached a large basin lying between the mountain range dominated by Mount Markham and the coastal range. In groups they explored and surveyed the basin, then returned to the ice shelf in time for Christmas there. After a spell of bad weather, they moved along the coast and re-supplied from a depot laid earlier by the RNZAF Antarctic Flight Beaver near Mount Asquith. Goldschmidt and Robb now sledged back towards "Scott base" to recover the second Sno-cat, which had been left at Cape Selbourne; and were transported for part of the way by the Beaver. The remainder of the party continued towards Mount Hope and, after completing their survey, waited to be collected by the Beaver. One sledge group had been flown to a survey position some 50 miles to the west of Mount Hope when, on the return journey to collect the other group, the aircraft crashed. The two field parties were then returned to "Scott base" on 19 January 1960 by a United States aircraft. The New Zealand airmen were unhurt and able to communicate with "Scott base" by radio; they were eventually rescued by the New Zealand Auster, but the Beaver is probably beyond salvage.

[1] *Polar Record*, Vol. 9, No. 60, 1958, p. 263.

Victoria University of Wellington Expedition to Victoria Land, 1959–60

A party from the Victoria University of Wellington worked in the ice-free area of Victoria Land during the summer of 1959–60, in continuation of the work carried out the previous year by another party from the same university.[1] The area is described[2] as being "between lats. 77° and 77° 45′ S. and between longs. 160° and 163° E.... The region consists of continental rocks, whose maximum altitude increases from about 5,000 ft. near the coast to 8,000 ft. It is transected by two major east–west valley systems associated with the Wright Glacier in the south and the Victoria Glacier farther north. Both valleys are more than 40 miles long." Members were: R. W. Balham (leader), biologist and meteorologist, R. H. Wheeler (deputy leader), A. Allan, and G. Gibson, geologists, and I. Wills, collecting samples for palaeomagnetic examination.

The party was transported throughout by United States aircraft and ship. After arrival at "Scott base" a reconnaissance and photographic flight was made in an Otter aircraft, and the party were then taken by helicopter to set up a base at "Lake Vashka", in the Victoria Glacier Valley. With the aid of the helicopter, three depots were set up, one at the lower end of the valley and two high-level ones at about 3000 ft.

While the main party worked from the depots, Balham carried out meteorological and biological studies in the area around "Lake Vashka", collecting lichens, mosses and algae, making analyses of the fresh water in the lakes while collecting plankton, and studying desiccated corpses of seals and birds found on the valley floor. Corpses of Weddell Seals, Crabeater Seals and Skuas were found 40 miles from the sea. The party spent 66 days in the field and completed a general exploratory survey of some 2,500 sq.miles. The geologists, in 600 miles of foot traverse, mapped the pre-Cambrian metamorphic basement, the younger Beacon sandstones, and the intruded dolorites and granites, discovering that the thickness of the Beacon series is approximately 3,500 ft., considerably more than was previously thought. Seven survey stations were established to tie in with survey work done during the previous year's expedition and the Commonwealth Trans-Antarctic Expedition.

The average temperature at the base camp was 29° F. (−2° C.) and the extremes were 54° F. (12° C.) and 8° F. (−14° C.). Winds were predominantly from the east, in contrast to the katabatic and anabatic winds experienced in the Wright Glacier valley the year before. The party left the area on 1 February 1960 by helicopter.

New Zealand Soil Survey in Ross Dependency, 1959

Two members of the New Zealand Soil Survey, Department of Scientific and Industrial Research, spent October and November 1959 working in the McMurdo Sound area. They were G. C. Claridge, chemist and mineralogist, and J. D. McCraw, pedologist. The objects of their work were: to search for any evidence of soil-forming processes operating in the area; to search for buried soils, or other evidence of changing climate; to study past and present rock weathering; to study permafrost, especially in its relationship to topography; and to collect general botanical and geological information.

After arrival, by United States aircraft, at "Scott base" a number of short trips were made before the main project began. Motor-sledge trips were made to study volcanic soils at Cape Royds, and to visit Cape Evans. Flights were made over the ice-free areas of Victoria Land, including the valleys of Victoria Glacier, Wright

[1] *Polar Record*, Vol. 9, No. 63, 1959, p. 573–74.
[2] *Antarctic*, Vol. 2, No. 2, 1959, p. 50.

Glacier and Taylor Glacier, and finally to Cape Hallett, where the soil of the large penguin rookery was examined.

The main journey was to the Taylor Glacier Dry Valley and was made by tractors and sledges. The route was to one of the Dailey Islands, up Koettlitz Glacier and back to Cape Chocolate, where some time was spent on the terraces and fans at the foot of Hobbs Glacier. The tractors left Claridge and McCraw at a camp near the entrance to the Taylor Glacier Dry Valley and returned to "Scott base". The two men worked up the valley carrying out a detailed study of frost phenomena and were then flown back to "Scott base", by way of Marble Point, by United States helicopter on 19 November; their projected journey on foot to Marble Point being prevented by the state of the sea ice.

Preliminary work on the samples and data collected has established that, although soils as an agriculturalist knows them do not exist in the area, soil-forming processes do operate there. The most striking evidence was a widespread surface crust of time-cemented sand about 2 in. (5 cm.) thick, implying that chemical weathering takes place and lime is deposited from evaporating soil moisture. A notable feature was the amount of physical weathering taking place, rock splitting, disintegration, sculpturing and sand and ice blasting.

Oceanographic work from HMNZS Endeavour, 1960

A party of six under Lieut. R. Adams carried out oceanographic work from *Endeavour* after the re-supply of "Scott base" had been completed, though adverse weather curtailed the programme considerably.

Two cruises were made, one, between 20 and 25 January, in the McMurdo Sound area, and another, between 30 January and 9 February, across the Pennell Bank in the Ross Sea. During both cruises collections were made of biological, hydrological and bottom-sediment samples. A collection of bulk samples for ^{14}C determination was made over the continental slopes of the Ross Sea. Dredging was carried out off Scott Island. Temperature measurements were made in the region of the Antarctic Convergence. The proton magnetometer was operated during both cruises, and marine seismic measurements were carried out whenever weather and other conditions permitted.

New Zealand Alpine Club Expedition to Victoria Land, 1959–60

A party of five members of the New Zealand Alpine Club, led by R. W. Cowley, carried out a programme of geological and topographical work in the mountains to the east of the Beardmore Glacier between 11 November 1959 and 13 January 1960.

They were transported from New Zealand to "Scott base" and then on to "Beardmore Depot" on the Ross Ice Shelf about 30 miles from the ice front, by United States aircraft. From there they man-hauled their supplies and equipment to a base depot near the foot of a glacier some 15 miles east of the mouth of the Beardmore Glacier. The party, together or in groups, then worked for 6 weeks in the area around Mounts Cyril, Kyffin, Scott, and Kathleen, carrying out topographical and geological surveys and collecting lichens, fungi and, in lat. 83° 50′ S., a number of small insects. Early in January the party were flown back to "Scott base" on 7 and 11 January 1960 by the RNZAF Antarctic Flight Beaver aircraft.

During their field work, they sledged about 180 miles, surveyed some 1000 sq.miles, and collected 150 lb. of specimens.

SOVIET ANTARCTIC EXPEDITION, 1959–60

[Summarized from *Vodnyy Transport* and announcements over Moscow Radio.]

During the southern winter of 1959, the Soviet Antarctic Expedition manned three stations—"Mirnyy", "Vostok" and "Lazarev".

Operations from "Mirnyy". The main feature of the 1959–60 programme was an overland journey to the South Pole, with glaciological work as the primary object. For this purpose three 34-ton "Khar'kovchanka" vehicles had been driven from "Mirnyy" to "Komsomol'skaya" at the end of the 1958–59 season, and left there unattended for the winter. A party left "Mirnyy" on 27 September 1959 in five "Pingvin" vehicles, arriving at "Komsomol'skaya" on 19 October. Aircraft now flew in from "Mirnyy", bringing more members of the overland party and supplies. On 6 November the main party left "Komsomol'skaya" in three "Khar'kovchankas" and two "Pingvins", each pulling sledges. In spite of difficult soft snow "Vostok" was reached on 29 November. Here more supplies were flown in, and modifications carried out to the tracks of the "Khar'kovchankas". The party, now led by A. G. Dralkin, the leader of the Fourth Soviet Antarctic Expedition, left on 8 December with two "Khar'kovchankas" and one "Pingvin". Conditions were somewhat easier, sastrugi replacing soft snow, and the South Pole was reached on 26 December. The return journey, by the same route, was started three days later. The vehicles were left at "Vostok", which they reached on 8 January 1960, and the sixteen members of the party were flown to "Mirnyy". Five glaciologists under B. A. Savel'yev took part in the traverse, and stops were made every 100 to 200 km. for seismic soundings and other scientific work. The original plan had been to continue from the Pole to the Pole of Inaccessibility, and then either on to "Lazarev" or back to "Mirnyy", but it was evidently not possible to adhere to this.

Another traverse party made more detailed observations, particularly of altitudes and ice thicknesses, along part of the same route. This was a party of seven under S. N. Shcheglov, travelling in two "Pingvins". It covered the first 150 km. southwards from "Mirnyy" during the winter (23 April to 8 July 1959), and left again on 14 September to continue southwards. "Komsomol'skaya" was reached in early January 1960, and the vehicles were left there, the men being flown out in time to catch the relief ship.

The winterers at "Vostok" were relieved in early January also. The new team of ten was led by V. Sidorov, who had wintered at "Vostok" in 1958.

In preparation for next season's inland journeys, a tractor train hauling fuel left "Mirnyy" for "Komsomol'skaya" on 26 February, and having completed the assignment, returned on 9 April.

Operations from "Lazarev". The relief ship *Ob'* this year went first to "Lazarev". She arrived on 19 December 1959, and disembarked not only the new "Lazarev" wintering party of ten men under L. Dubrovin, but 50 more members of the Fifth Soviet Antarctic Expedition, together with their leader Ye. S. Korotkevich, for summer work in Dronning Maud Land. New buildings were erected at the station. Geological parties under D. Solov'yev set up, with air support, two advance camps in the mountains between longs. 8° E. and 10° E. Glaciological, meteorological, magnetic and biological work was done in and around "Lazarev". Air reconnaissance of possible routes into the interior was carried out, together with an air survey programme. A tractor train set out from "Lazarev" about 22 January 1960 and travelled 110 km. southwards, five seismic soundings being made *en route*.

Next season it is planned to move the station 100 to 150 km. inland to the northern part of the mountains, converting it into a long-term scientific and supply centre. A major traverse to the Pole of Inaccessibility from here is also under discussion.

Flying operations. Most flying was in support of ground parties, but among other flights made were the following. A preliminary long-distance flight from "Mirnyy" to "Lazarev" and back, calling at intervening stations en route, was carried out by B. Osipov in an IL-12 between 12 October and 1 November 1959. This route was followed by several aircraft carrying men who had been working in the "Lazarev" area to "Mirnyy". The first of these flights was made on 11 January 1960 in a recently disembarked IL-14, the heaviest aircraft yet used by the Soviet expeditions. Korotkevich was on this flight, which reached "Mirnyy" non-stop in eleven hours. In January also an LI-2 aircraft from "Lazarev" carried out ice reconnaissance at Belgian request in order to assist *Erika Dan* in finding a way into "Roi Baudoin" station.

Ship operations. The *Ob'* left "Lazarev" on 28 December 1959 and, continuing her voyage, gave assistance to the *Soya* during the first week in January 1960, helping her both into and out of the Japanese station "Syowa", called at Mawson, and arrived at "Mirnyy" on 14 January. Aircraft fuel was left at both "Syowa" and Mawson for future flying operations. *Kooperatsiya*, the other relief ship, had arrived at "Mirnyy" on 7 January. The two ships brought to the Antarctic some 300 people, including scientists from Czechoslovakia, East Germany and the United States. The ships departed on 1 February, leaving 120 winterers in Antarctica. *Kooperatsiya* went straight home, but the *Ob'* continued her oceanographic programme in the Southern Ocean, this part of the expedition being led once again by I. V. Maksimov. Continuing eastwards, the *Ob'* visited the Balleny Islands and Scott Island, and on 9 March reached Peter I Øy. On the next day she cruised round the island, sounding and surveying the coast by radar and photography, but no landing was made. When she left Antarctic waters shortly afterwards, she had all but completed a circumnavigation of Antarctica, much of it south of lat. 65° S.

UNITED STATES ACTIVITIES IN THE ANTARCTIC, 1959–60

[Summarized from information in *Bulletin of the United States Antarctic Projects Office*, Vol. 1, Nos. 1 to 7, and private communications.]

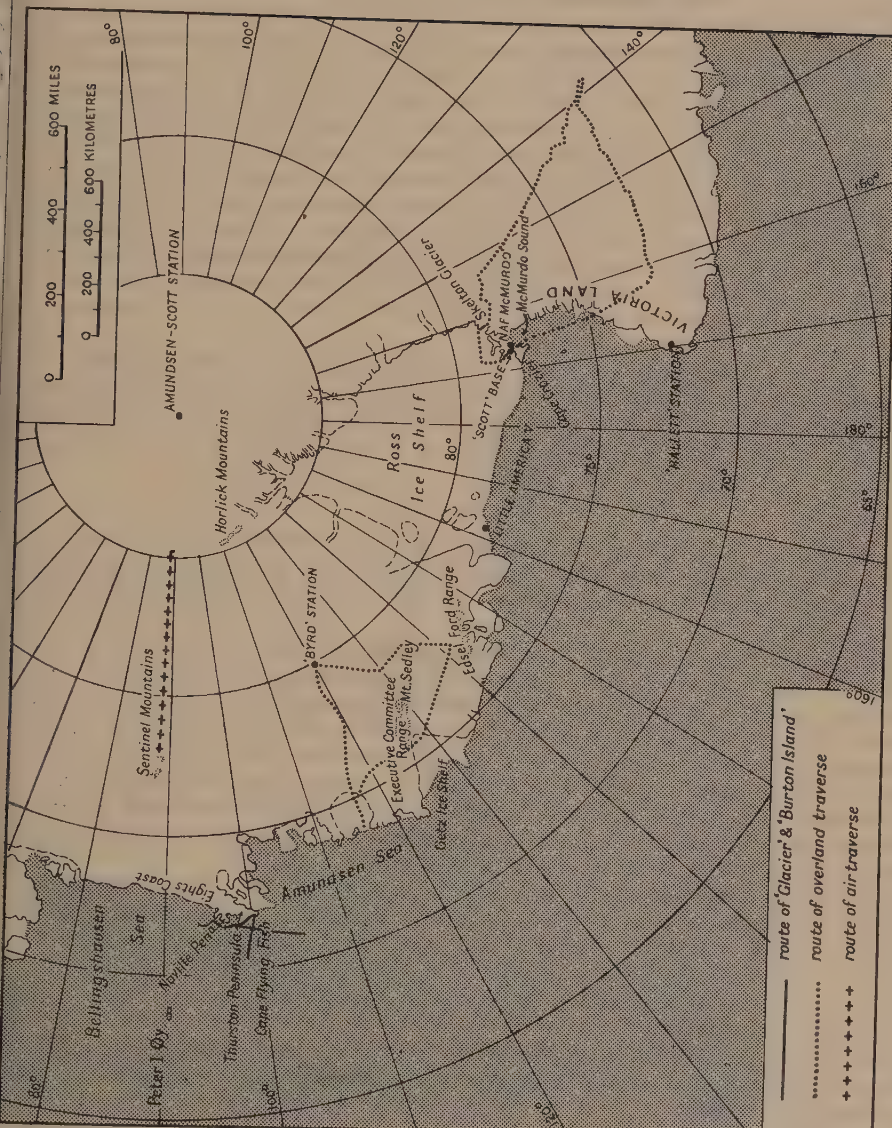
Operation "Deep Freeze 60", 1959–60

United States scientific activities in the Antarctic, in continuation of the work begun during the International Geophysical Year (Operations "Deep Freeze I" to "IV"), were administered by the National Science Foundation through the United States Antarctic Research Program. Logistic support was again provided by Task Force 43 of the United States Navy, with Admiral D. M. Tyree as commander. Admiral Tyree arrived at "NAF McMurdo" from New Zealand on 1 October 1959. The first supply flights were made on 16 October and all supply aircraft had left Antarctica by 6 February 1960 (see p. 298).

Supply vessels of Task Force 43 arrived in McMurdo Sound early in January 1960; they included the icebreakers *Atka*, *Burton Island*, *Glacier*, *Eastwind* and *Staten Island*; the cargo ships *Arneb*, *Alatna*, and *Private John R. Towle*; while *Peterson* acted as "ocean station vessel" between New Zealand and the Ross Sea.

Victoria Land traverse

This traverse was led by F. G. van der Hoeven, seismologist, and included T. T. Baldwin, transport officer; A. J. Heine, a New Zealand surveyor; W. A. Jackman, photographer; C. Lorius, a French glaciologist; L. J. Roberts, cartographer; W. M. Smith, psychologist; A. W. Stuart, glaciologist; and J. G. Weihaupt,



Sketch map showing United States activities in Antarctica during Operation "Deep Freeze 60", 1959–60. Ship tracks are shown only in vicinity of "Thurston Peninsula".

sesimologist. The party used three Sno-cats and were re-supplied by R4D Skytrain aircraft during the journey.

The party left from "Scott base" on 16 October 1959 and reached the former Commonwealth Trans-Antarctic Expedition depot at the foot of Skelton Glacier on 1 November. The ascent of the glacier took eight days owing to bad weather and visibility. Measurements were made of the ablation and accumulation stakes set up during the 1957–58 traverse; near the top of the glacier accumulation was 29 cm. in 11 months. The route then lay south-west to connect with the southern limit of the French traverse in 1957[1] (lat. 70° 47′ S., long. 139° 12′ E.) and on to reach the farthest point in lat. 71° 09′ S., long. 139° 12′ E. The party then turned east and continued for some 600 miles towards the Victoria Land coastline. Part of this section of the journey was made across the direction of sastrugi, and one of the Sno-cats had to be abandoned owing to the damage it sustained. Air reconnaissance had indicated mountains between longs. 161° and 162° E. and these were surveyed by the party. A large ice stream was also reported, and photographed, flowing into Rennick Bay. About 180 miles from "Hallett" station the traverse vehicles were abandoned and the men flown back to "NAF McMurdo" by Skytrain on 12 February, after a journey of 1530 miles.

During the traverse seismic soundings were made at intervals of 30 to 40 miles on every second or third day, and latterly at less frequent intervals. Glaciological pits were dug at seismic stations and samples taken for deuterium and tritium content. Vertical magnetic records were made at intervals of 3 to 5 miles.

Airborne traverses

An Airborne Traverse party consisted of E. Thiel, leader and geophysicist, E. S. Robinson, geophysicist, and J. J. Anderson, geologist; C. Craddock replaced Anderson during December. Transport was by means of United States Navy R4D (DC-3) aircraft.

Tidal study on Ross Ice Shelf. This continued studies made by A. P. Crary and Thiel at "Little America V" and "Ellsworth", by measuring the change in gravity resulting from the rise and fall of the ice shelf in response to the ocean tide. This season the object was to determine whether the tidal effect noted at the ice front extended far "inland" underneath the Ross Ice Shelf. The party were transported by air to a point near the centre of the ice shelf and several hundred kilometres from the ice front. Gravity measurements were taken at 20-min. intervals for 3 days. This data showed that the tidal effect does extend as far as this point, and is of comparable magnitude to that noted at the ice front.

Airborne magnetic traverses. Profiles, using a Varian proton processional magnetometer, were flown for a second season and consisted of flights between "NAF McMurdo" and "Hallett", "Byrd" and the "Amundsen–Scott" South Pole stations. The magnetometer was also towed on reconnaissance flights to the north, east and south of "Byrd", and a detailed survey of Ross Island was made with flight lines 5 miles apart.

Gravity traverses. A high range Worden gravity meter was carried during all the magnetic traverses in order to make ties between stations and strengthen the continental gravity network.

Geophysical and geological studies along long. 88° W. The object of this, the most important project of the season, was to establish the possible existence of a deep trough connecting the Ross Sea and the Weddell Sea, and also to study the geological transition across a section of Antarctica by visiting nunataks reported to occur along this meridian. Eight landings were made between the Sentinel Mountains

[1] *Polar Record*, Vol. 9, No. 60, 1958, p. 255.

and the Horlick Mountains, four for seismic soundings of ice thickness between the nunataks, and four for geological observations. The main conclusion reached as a result of the traverse is that no large trough exists between the Ross Sea and the Weddell Sea (the greatest distance between nunataks is 90 miles) but that the continuity of the land is probably interrupted by narrow troughs, since several of the soundings between nunataks showed a rock surface below sea level. The ice is grounded so there is no possibility of water exchange between the two seas at the present time.

Other flights. A number of reconnaissance flights were made over little-known parts of the continent; "Thurston Peninsula" was observed to be an island connected to the mainland by an ice shelf (see p. 289), and what may be a new range of mountains was reported along the Eights Coast.

Investigations in McMurdo Sound. During November 1959 the party made a ground traverse by Sno-cat across McMurdo Sound from "NAF McMurdo" to Inaccessible Island and back. Seismic soundings were made at intervals of 9 miles, and gravity and magnetic measurements every 3 miles.

"Byrd" station traverse

The party, consisting of J. Pirrit, leader and glaciologist; G. A. Bennett, transport engineer; F-K Chang (China) and G. A. Doumani (Lebanon), seismologists; K. E. Marks, electronics engineer; and P. E. Parks, Jr., geophysicist, travelled with 4 Sno-cats and left "Byrd" station on 6 November 1959. Fuel and supply depots had been set up by R4D aircraft and by the "Little America V"–"Byrd" station tractor train earlier in the year.

Progress was hindered at the outset by blizzard and whiteout conditions, but a previous reconnaissance flight had shown that the route was free of crevasses and the party pushed on in spite of poor visibility. They examined an ice shelf on the coast of the Amundsen Sea, in lat. 74° 5′ S., long. 115° W., and then reached its ice front on 22 December in lat. 73° 58′ S., long. 116° 11′ W. The ice front, here about 100 ft. high, was reported to be some 30 miles south of its plotted position. The Amundsen Sea was open water containing floes and ice bergs drifting north. The party then turned west towards the Getz Ice Shelf. By means of surface topography and altimeter readings taken during a reconnaissance flight, this ice shelf was discovered not to extend as far south as had been thought and to consist only of a narrow coastal belt north of lat. 75° S. The traverse continued westwards as far as the southern end of the Edsel Ford Range. By early February, after several periods of blizzard, they reached Mile 400 of the "Little America V"–"Byrd" trail and arrived at "Byrd" on 9 February 1960. During the traverse over 100 uncharted nunataks were discovered and surveyed, very few of which could be identified as mountains shown on the present maps. All were composed of volcanic rock except for a small granite batholith in the Edsel Ford Range. The highest peak visited was Mount Sedley, in the Executive Committee Range, 13,850 ft. (4,220 m.).

Altimetry, magnetic and gravimetric observations were made at intervals of 3 nautical miles; rammsonde measurements were made every 6 nautical miles; survey, and seismic soundings every 30, and later 36, nautical miles, when 3 m. pits were also dug for glaciological studies.

University of Michigan glaciological work on the Ross Ice Shelf

A four-man expedition organized by the Geology Department, University of Michigan, left New Zealand on 5 December 1959 on the USS *Arneb*. Members were J. H. Zumberge and C. W. M. Swithinbank, glaciologists; J. E. Schroeder, surveyor; and F. J. Jacobi, mechanic. The object of the expedition was to measure the rate of

movement of the Ross Ice Shelf. Four days after *Arneb* arrived off "Little America V" on 14 December, the party set out for McMurdo Sound with two Model 443A Sno-cats. A United States Navy ski-equipped Otter aircraft landed near "Camp Michigan" on 20 December and Zumberge was replaced by J. B. Long, a mechanic. The Sno-cats then proceeded westwards across the ice shelf, covering 20 miles daily. At each camp, sun altitudes were measured every three hours when weather permitted, and a stake pattern was set up to measure surface strain rates. A Sno-cat breakdown on 31 December required four Otter flights in persistent whiteout and low cloud while searching for the party to deliver spare parts. The Sno-cats arrived at "NAF McMurdo" on 11 January 1960, after a journey of 460 miles. In all, 12 points were fixed for ice movement studies; it is proposed to repeat the measurements in 1962 to find the amount of ice movement. In addition, 1800 snow accumulation stakes were measured, 13 pits were dug for density measurements and 21 strain stake patterns were set up. Swithinbank remained at McMurdo Sound until 13 March. Assisted by J. J. Mulligan, he resurveyed an ice movement stake planted by A. P. Crary in 1957 at United States "NAF Beardmore". Later, travelling in a United States Navy helicopter and assisted by E. S. Robinson, A. W. Stuart, and S. Evteev (a Russian exchange observer), he set up and surveyed ice movement stakes near Cape Crozier, between Black Island and Mount Discovery, between Black Island and White Island, and near the ice front in McMurdo Sound. The members of the expedition returned separately to New Zealand in vessels of the United States Navy.

Bellingshausen Sea Expedition

During February 1960 USS *Glacier* and *Burton Island* were successful in reaching the coast of Antarctica south of the Bellingshausen and Amundsen Seas. There they carried out a topographical and scientific survey of the coastal area between longs. 94° W. and 102° W. The ships were under the over-all command of Captain E. A. McDonald, Deputy Commander, United States Naval Support Force, Antarctica. They carried a party of eleven scientists working under the auspices of the National Science Foundation and headed by P. M. Smith.

The *Burton Island*, Commander G. C. Evans Jr., left Valparaiso on 28 January 1960 and reached Peter I Øy after making regular oceanographic observations along the route. The ship then sailed south to the ice edge, thence west to meet the *Glacier* (which had left Wellington on 7 March) in lat. 71° S., long. 104° W., on the 15th. The two icebreakers then sailed together on a south-easterly course towards Cape Flying Fish, and, after an unexpectedly easy passage through the pack ice, made a landfall in lat. 71° 50′ S., long. 102° 15′ W. They continued eastwards making observations along a 1 to 3-mile wide coastal lead. An automatic weather station was established on Noville Peninsula in lat. 71° 54′ S., long. 99° W., 500 m. above sea level. Eventually progress to the east was halted by ice in long. 95° 44′ W.; *Glacier* remained there to conduct studies ashore while *Burton Island* returned westwards for the same purpose.

Parties from *Glacier* continued the eastwards exploration of the Eights Coast by helicopter, then the icebreaker moved west to rejoin *Burton Island* in lat. 71° 52′ S., long. 100° 52′ W. At this point a request for assistance was received from the Argentine icebreaker *San Martin*, beset in Marguerite Bay, and the programme was curtailed before the Amundsen Sea phase had begun. *Glacier* sailed east to Victor Hugo Island, then along the coast of Graham Land south-west towards the *San Martin* which, however, extricated herself from the ice. *Glacier* went on to the assistance of *Kista Dan*, on charter to the British FIDS party, and also beset in the area. She later continued observations in Gerlache Strait and Drake Passage and on Deception and Penguin Islands in the South Shetland Islands, reaching Buenos

United States "tractor train" in Antarctica.

Official United States Navy photographs

(*Facing p.* 288)

United States Navy P2V "Neptune" ski-equipped aircraft in flight over the Beardmore Glacier, Antarctica.

Aires on 10 March. Meanwhile the *Burton Island* went on to Peter I Øy and made numerous offshore soundings. A number of landings were made; Lars Christensentoppen was reported to be 5,700 ft. (1,740 m.) in altitude.

The insularity of "Thurston Peninsula" has been established beyond doubt as a result of this expedition. From observations from the ships, and from high-altitude air photographs taken in January 1960 by Air Development Squadron Six, USN, it has been found that this feature is an island separated from the continent to the south by a large ice shelf. This ice shelf extends from Peacock Bay on the west to a similar unnamed bay on the east, which separates "Thurston Island" from the Eights Coast. The island is a low snow-covered dome with occasional exposed or snow-covered mountains, an unindented southern margin, and a series of large north–south oriented, ice shelf-filled embayments on the north. Noville Peninsula may be a separate, small island connected to "Thurston Island" by an ice shelf. Astronomical control was established at the east and west ends of the island and near an exposure in lat. 71° 46′ S., long. 97° 33′ W.

To the east, on the Eights Coast, two new islands were sighted. Behind these the continental ice sheet rises gradually to the south. An inland range of high mountains was sighted in about lat. 74° S., long. 92° W. The so-called "Fletcher Islands" were not located; a number of large stationary icebergs were seen and from the distance it is believed that these may have been mistaken for the islands reported by the United States Antarctic Service Expedition, 1939–41, and Operation "Highjump", 1946–47.

The rocks examined at seven localities are granite gneiss bodies that have a north–east trend. These are cut by a series of post-metamorphic basic dikes. The ages of these rocks have not yet been determined. Coastal sediment cores and rock samples collected from an extremely irregular ocean bottom correlate well with the geological observations made ashore. The sediments collected range from boulders and cobbles to finely ground rock and plastic clay. Sand in gullies and abundant lichens, algae, and a few liverworts indicate that some ice and snow ablation occurs during the warmest months. At several rock outcrop areas there is evidence of a much more extensive ice cover in the past.

An entomological programme was carried out on shore at Deception Island and Penguin Island in the South Shetland Islands; no insects were found in the Bellingshausen Sea area.

The southern parts of the Bellingshausen and Amundsen Seas were marked by a notable scarcity of vertebrate life, particularly of birds. Only four species of bird were observed and these in small numbers. No suitable breeding sites for any species except the Emperor Penguin were seen, and none of the sites is known with certainty to have been a breeding ground of the Emperor Penguin. Adélie Penguins were even scarcer, usually represented by a lone bird, or sometimes two birds. A single Macaroni Penguin, *Eudyptes chrysolophus*, seen on an ice floe off "Thurston Island" on 23 February, represents a southernmost record for this species.

Oceanographical and gravity data, as well as cartographical, biological and geological information, is being analysed at the present time by the investigators who participated in the voyage. Detailed reports will appear in the appropriate scientific journals.

Summer parties at Antarctic stations

In addition to the activities already recorded, the following organizations took advantage of the logistic and other facilities available to make short-term summer investigations in three localities:

"*NAF McMurdo*"

(*a*) Bureau of Mines. Geological reconnaissance at Marble Point, Taylor Glacier, Mount Gran and dry valleys to the north of Mount Gran.

(*b*) Tufts University. Geomorphology in the dry valley areas in the region of the Taylor and Wright Glaciers.

(*c*) University of Kansas. Collection of specimens for thermoluminescence studies in Taylor Glacier Dry Valley and at Marble Point.

(*d*) Bishop Museum, Honolulu. Entomology.

(*e*) Stanford University. Marine biology.

(*f*) University of Texas. Microbiology.

(*g*) Virginia Fisheries Laboratory. Fish and parasite collections.

(*h*) Bartol Research Foundation. Cosmic Rays.

"*Wilkes*" *station*

University of Wisconsin. Biology, especially of Adélie Penguins.

"*Hallett*" *station*

University of Tennessee. Land invertebrate, and related micro-climatic, studies. (Also at "NAF McMurdo".)

Duke University. Biology of Adélie Penguins.

NOTES

ELEVENTH MEETING OF THE INTERNATIONAL WHALING COMMISSION, 1959, AND RELATED DEVELOPMENTS

[Summarized from *Norsk Hvalfangst-Tidende*, Årg. 48, No. 11, 1959, p. 557–62, and Årg. 49, No. 1, 1960, p. 1–12.]

The eleventh meeting of the International Whaling Commission was held in London from 22 June to 1 July 1959. Mr R. G. R. Wall (United Kingdom), chairman of the Commission, presided, and representatives of all seventeen contracting governments except Brazil and Panama were present. Portugal, the Food and Agriculture Organization of the United Nations and the International Council for the Exploration of the Sea were represented by observers.

A review of the 1958–59 Antarctic season was provided by the Bureau of International Whaling Statistics. Twenty factory ships with 235 catchers (2 catchers less than in 1957–58) took part in the pelagic operations. Pelagic operations for baleen whales began on 7 January and ended on 16 March (as in the previous season), when 15,300 Blue Whale units had been taken. The total pelagic catch was 30,824 baleen whales and 5437 Sperm Whales, from which were produced 1,798,449 barrels of whale oil and 251,794 barrels of sperm oil (at 6 barrels to the ton). By-products totalled 126,196 tons. The South Georgia catch from three shore stations totalled 2311 baleen whales and 215 Sperm Whales from which were produced 92,113 barrels of whale oil, 10,305 barrels of sperm oil, and 17,950 tons of by-products. The largest catches of baleen whales were taken in areas III (longs. 0° to 70° E.) and IV (longs. 70° to 130° E.) and accounted for 33·6 and 31·1 per cent respectively, of the total pelagic catch. The former sanctuary in the Pacific sector (longs. 70° W. to 160° E.) contributed only 9·1 per cent, compared with 25 per cent in the previous season.

One of the main difficulties facing the Commission and the industry has been the wasteful competition for the largest share of the catch quota. This means that costs are artificially high for the limited catch and approaching the level where economic operation is impossible. Only if this competition can be reduced, with a consequent reduction of expenditure, is there any prospect of reducing the annual catch to a level which the stocks of whales can stand without depletion. By the terms of the 1946 Convention, the International Whaling Commission is itself precluded from allocating separate quotas to individual countries or groups. In an attempt to overcome these difficulties, representatives of the five states with pelagic whaling expeditions in the Antarctic met in November 1958.[1] They unanimously recommended an agreement to last 7 years. During this period there were to be restrictions on the number of factory ships in the Antarctic and the annual catch quota was to be divided in the proportions of 20 per cent to the Soviet Union and 80 per cent between Japan, the Netherlands, Norway and the United Kingdom. The four countries were not able to reach an agreement on the allocation of the 80 per cent and it was resolved that negotiations should be resumed later. Several conferences were held in 1959, the latest in connexion with the International Whaling Commission meeting.

Meanwhile, Norway, the Netherlands and Japan (in that order) had given notice of their conditional withdrawal from the Convention, with effect from 1 July 1959, if agreement on the distribution of the quota could not be reached. No agreement could be reached even when a contemplated raising of the quota was taken into account. Japan cancelled her withdrawal, but the withdrawal of Norway and the Netherlands became effective on 1 July.

[1] *Polar Record*, Vol. 9, No. 62, 1959, p. 469–70.

The Scientific Committee had again expressed its concern about the state of the stocks of whales. In the absence of any resolution to the contrary the quota set for the pelagic catch remained at 15,000 Blue Whale units but applied only to the countries remaining within the Convention. Norway and the Netherlands announced that they would limit their catches to 5,800 and 1,200 Blue Whale units respectively. Japan and the United Kingdom later fixed national quotas of 5,000 and 2,500 Blue Whale units, but the Soviet Union has not yet made an announcement. The total catch in 1959–60 was 15,500 Blue Whale units. It was stated that Norwegian expeditions would adhere to all other provisions of the schedule, but the Netherlands was not prepared to adhere to the provisions relating to the catching period.

It was decided that the opening date for the taking of Fin and Sei Whales should be advanced to 28 December, with no change in the closing date (7 April). It was also agreed that the taking of Humpback Whales should be from 20 to 23 January inclusive, instead of 1 to 4 February as in previous years.

The protection of Blue Whales in the North Atlantic was discussed, and it was resolved that they should be protected for a further five years. The former sanctuary in the Pacific sector of the Antarctic is to be kept open for a further three seasons.

There is a provision in the schedule to the Convention that permits factory ships operating in certain territorial waters to be regarded as land stations (concerning the regulations applicable) if the ship belongs to the country having jurisdiction over those waters. This applies to certain areas round Madagascar, French West Africa and Australia. It was agreed that it should also apply to American ships operating within American territorial waters between lats. 35° N. and 49° N.

It was announced that the Protocol amending the Convention so as to permit the appointment of International Observers in addition to National Inspectors had been ratified by all contracting governments, and entered into force on 4 May 1959. Norway and the Netherlands had already withdrawn from the meeting when this question was raised. It was therefore agreed that Japan, the United Kingdom and the USSR should later have discussions on this subject, and that Norway and the Netherlands should be invited to attend. An attempt would be made to draw up a draft agreement.

The question of the humane killing of whales was raised and after some discussion it was decided that the Chairman and Secretary should organize a small body to consider the available evidence and prepare a report to the Commission.

Other points dealt with included provisions relating to the use of helicopters, refrigerated ships, and meat for local consumption.

The next meeting of the Commission will be held in London, beginning on 20 June 1960. The *ad hoc* Scientific Committee will meet in May.

DANISH ICE RECONNAISSANCE SERVICE IN GREENLAND

[From information provided by Den Kongelige Grønlandske Handel.]

The Ministeriet for Grønland is responsible for the organization and operation of an ice-reconnaissance service based on the airfield at Narssarsuaq, south-west Greenland, acquired from the United States authorities in 1958. The runway, 6,500 ft. long by 200 ft. wide, has a concrete surface, and there is a generous provision of ancillary buildings and services.

The aircraft used are Canso amphibians belonging to the Royal Danish Air Force, carrying navigators supplied by Den Kongelige Grønlandske Handel. The service, with the dual purpose of observing the ice movement in the Arctic basin and supplying information to ships navigating in south Greenland waters, operates

throughout the year. Ice reports in plain language (Danish and English) are available from radio stations at Prins Christian Sund and Frederikshåb, and are transmitted daily at 16.00 hr. in morse from Angmagssalik. Ice information may also be obtained on request from "Iscentralen Narssarssuaq".

FIRST INTERNATIONAL SYMPOSIUM ON ARCTIC GEOLOGY, 1960

[By W. B. Harland, Department of Geology, University of Cambridge.]

The First International Symposium on Arctic Geology, sponsored by the Alberta Society of Petroleum Geologists, was held in Calgary, Canada, on 11–13 January 1960. It was attended by over 1,000 delegates of whom some 700 lived in Calgary itself. Official delegations were invited from those countries having Arctic territories, and papers were invited from these delegates and many others. Abstracts from 80 papers were published before the meeting.

The sessions were held as follows:

11 January

Morning.	Chairmen: T. A. Link and C. S. Lord. Regional tectonics. 5 papers.
Afternoon.	Chairmen: J. C. Scott and W. B. Harland. Tectonics. Pre-Cambrian geology. 7 papers.

12 January

Morning.	Chairmen: P. F. Moore and K. Ellitsgaard Rasmussen. Stratigraphy. 7 papers.
Afternoon.	Chairmen: R. H. Erickson and V. N. Sachs. Stratigraphy. Submarine geology. 8 papers.

13 January

Morning.	(*a*) Chairmen: K. Mygdal and K. C. Reed. Arctic Canada. Alaska. 11 papers.
	(*b*) Chairmen: J. Kirker and J. T. Wilson. Geomorphology. Pleistocene geology. 10 papers.
Afternoon.	(*a*) Chairmen: W. B. Gallup and L. Koch. Permafrost. Sea ice. 11 papers.
	(*b*) Chairmen: J. C. Sproule and B. C. Heezen. Exploration. Technique. Logistics. Climate. 12 papers.

Publications arising from the Symposium are to be: (*a*) *The geology of the Arctic: a report of the First International Symposium on Arctic Geology*; (*b*) a geological map of the Arctic, scale 1:5,000,000; (*c*) a tectonic map of the Arctic, scale 1:5,000,000; (*d*) a bathymetric chart of the Arctic Ocean, scale to be announced.

During the Symposium, in addition to numerous technical and commercial exhibits, there were substantial exhibits of results of geological work carried out by the geological survey departments of Canada, the United States and Greenland, and Institut Geologii Arktiki [Institute of the Geology of the Arctic] in Leningrad. Papers included results from the above organizations, also from Norsk Polarinstitutt and Geologinen Tutkimuslaitos [Geological Survey of Finland].

It was resolved that further symposia would be desirable and that their organization should be discussed at the Geological Congress to be held in København later in the year.

OHIO STATE UNIVERSITY: INSTITUTE OF POLAR STUDIES

The Institute of Polar Studies of the Ohio State University was established in February 1960 and is under the direction of R. P. Goldthwait, professor of Geology. The objects of the institute are given as (*a*) to plan, support and direct significant scientific research in polar phenomena; (*b*) to bring together investigators of polar areas; (*c*) to facilitate and encourage the training of polar research workers; (*d*) to make the results of polar research available.

The area of study is defined as "the environment where ground is permanently frozen, or glaciers are nearby". The subjects of study are bacteriology, glacial geology, glaciology, ice physics, lichenology, marine zoology, microclimatology, palaeobotany, photogrammetry, plant ecology, soil sciences, bed-rock geology and allied sciences.

In addition to teaching staff in the various subjects there are to be a number of research associates, either graduate students or full-time research workers. The standard graduate curricula of the university is to be adapted to polar emphasis, an interdepartmental polar seminar and some new courses (polar geography, lichenology and glaciology) may be introduced, and visiting staff sponsored. Technical and reference facilities are provided.

UNIVERSITY OF SASKATCHEWAN: INSTITUTE FOR NORTHERN STUDIES

[By Professor J. B. Mawdsley, Director, Institute for Northern Studies, University of Saskatchewan.]

The recently formed Institute for Northern Studies in the University of Saskatchewan has as its object the acquisition of new knowledge regarding the Canadian north, and the academic training of personnel in fields of study having a bearing on the north. It plans to aid staff members, graduate students and post-doctorates who wish to carry out research in this area under the guidance of the University's various departments. Besides various lines of investigation in the field of the natural sciences there are important problems to do with the native peoples of this region. The approach will be academic and close co-operation between the various disciplines, it is hoped, will be fostered and thus broaden and add to the value of the results obtained. There is no thought of competing or overlapping with other institutions or bureaux working in this vast field; there is plenty of work that needs to be done.

It is not at present planned to carry out research in the Arctic but rather in the sub-Arctic as far as the northern fringe of settlement. As more than half of Saskatchewan lies within this region, some of the work of the Institute will be carried out here. It is territory containing most of the problems common to northern Canada, it is relatively cheaply and easily accessible, and should prove to be an excellent area for research and training. More distant fields will be investigated as the need arises and when trained personnel is available.

In the summer of 1960 a modest beginning is being made. In the fields of biology and plant ecology a team of three graduate students will carry out a reconnaissance at three points in northern Saskatchewan; a small part of a large geological programme will be supported by the Institute; and two graduate students intend to investigate government and other records concerned with northern economic matters.

ROYAL CANADIAN AIR FORCE: SEARCH AND RESCUE SERVICES

[Note provided by Royal Canadian Air Force.]

RCAF search and rescue services in Canada may be conveniently considered under three headings. They are: cases involving aircraft; marine cases; and mercy flights.

Aircraft cases. Search and rescue services for aircraft in distress in Canadian territory, and in adjacent oceanic areas, are provided for by the Federal Government and are administered by the RCAF. The RCAF maintains special facilities for the co-ordination and execution of search and rescue operations and, through such facilities dispersed at strategic locations across the country, is constantly in a state of readiness for action in the event of a distress incident. The search and rescue aircraft and associated facilities may be supplemented, as occasion demands, by other military aircraft, the resources of other federal and provincial agencies, and the contribution of civilian volunteers. The RCAF exercises control of search and rescue through Rescue Co-ordination Centres (RCCs) and the system operates in close conformity with the principles endorsed by the International Civil Aviation Organization, of which Canada is a contracting state.

The RCCs are five in number and are located at Torbay, Newfoundland; Halifax, Nova Scotia; Trenton, Ontario; Winnipeg, Manitoba; and Vancouver, British Columbia. In addition there is a Rescue Co-ordination Sub-Centre at Edmonton, Alberta, under control of the Winnipeg RCC. The major search and rescue flying units are located at Torbay, Newfoundland; Greenwood, Nova Scotia; Trenton, Ontario; Winnipeg, Manitoba; and Vancouver, British Columbia. Small search and rescue flights are also maintained at Fort Churchill, Manitoba, and at Goose Bay, Labrador.

The types of aircraft in use for search and rescue are Canso, Dakota, Lancaster, Otter, H-21 helicopter and H-34 helicopter; they are established at the units mentioned above in various combinations depending on the topography and climate of the areas involved. They have all been specially modified for search and rescue and each type has been selected to fill a specific need. The Dakotas are operated in a ski-wheel configuration during the winter months to provide a rescue capability in the northern regions, where airfields are relatively few and widely separated. A long range rescue capability for summer operations is provided by the Canso amphibian. This aircraft is to be retired from RCAF service in the near future and will be replaced by the Grumman Albatross. The Lancasters are equipped to drop rescue equipment to survivors in either an ocean or an inland distress situation. In addition, they are used to intercept and escort distressed aircraft, particularly over the oceanic approaches to Canada, and their range and speed characteristics make them suitable for search operations anywhere in the country. The Otters operate on ski-wheels, floats or amphibious floats, depending on the season and the local situation. They are used primarily for short range rescue operations. The helicopters complete the fleet of rescue aircraft, providing a capability of vertical take-off and landing.

These facilities are supplemented by teams of para-rescue personnel who are trained to parachute to the scene of a crash to render first aid and other practical assistance to survivors and to assist in the rescue operation. In addition, major RCAF stations maintain ground search parties to support search and rescue operations.

Marine cases. The RCAF is responsible for co-ordinating assistance to marine craft through its established RCCs. The resources maintained for dealing with aircraft incidents are also used on marine cases wherever they can be usefully applied. All government agencies that possess suitable facilities, including ships, contribute to marine search and rescue under the direction of the RCC. Volunteer assistance from mariners, acting in the interest of mutual protection, is also encouraged.

Mercy flights. Action on behalf of individuals who become lost or require assistance in an emergency is, generally speaking, the responsibility of Provincial authorities. However, the RCAF assists in such cases on the request of the agency having principal responsibility.

Canada is divided into four areas of responsibility, Atlantic, Eastern, Western and Pacific. The main factors influencing the somewhat irregular division of territory are the relative density of air traffic in the different regions, the distribution of communications and other facilities essential to the control and conduct of search and rescue operations, and the incidence of past searches as determined from statistics covering the last decade.

About 85 per cent of all the aircraft for which search operations have been required in Canada in recent years have been civilian, as opposed to military, aircraft. The great majority have been small privately owned aircraft or light aircraft flown in non-scheduled commercial operations. The use of light civil aircraft in the Arctic has shown a marked increase in the last year or two and continued growth of such traffic is expected; however, despite this trend no major search operations were required in the northern parts of Arctic Canada during 1959 and the first quarter of 1960.

The Western search and rescue area includes most of the Canadian Arctic and the rescue co-ordination centre and flying unit are located at Winnipeg. The rescue unit is equipped with Lancasters, Dakotas, Otters and H-34 helicopters, and in the near future will be acquiring two Albatross aircraft. Supplies of aviation fuel are stored at strategic locations throughout the north especially for search and rescue purposes; during search operations an advance base is established at the most suitable location, having regard to the adequacy of the airfield and accommodation, communications facilities, proximity to the scene of operations and the like.

The radar stations of the Mid-Canada Line and the DEW Line are a tremendous asset to search and rescue operations in northern Canada. These units are frequently able to provide track information on missing aircraft and the communications network associated with the system is very useful in the conduct of search operations. In addition, the radar advisory service provided to aircraft generally tends to enhance the safety of flights in this region and thus reduce the frequency of search and rescue incidents.

It is interesting to note that the number of flying hours expended on search and rescue operations has not increased significantly over the past decade despite an impressive growth in the annual volume of air traffic. Moreover, the number of unsuccessful searches has been declining gradually; during 1959, in fact, all searches terminated with the successful location of the missing aircraft. These operations were 31 in number and were concerned with 4 military and 27 civilian aircraft. The degree of success is the more impressive when it is considered that in many cases the region involved was remote, uninhabited, heavily wooded or mountainous, making search operations difficult.

Search and rescue: Summary of operations during 1959

Number of major search operations	42
Number of operations involving life saving	19 (involving 49 persons)
Number of operations in which para-rescue teams were dropped	3
Number of search operations for military aircraft	4 (RCAF 3; USAF 1)
Number of search operations for civilian aircraft	27 (all successful)
Number of major marine search operations	5
Number of search operations for missing persons	6
Number of mercy flights	152
Total hours flown on all SAR activities for 1959	5527 hr.

ROYAL CANADIAN AIR FORCE: SURVIVAL TRAINING SCHOOL

[From information provided by Squadron Leader A. M. Sharp, RCAF Survival Training School.]

The RCAF Survival Training School is a detachment of RCAF Station Namao, which is in the Air Transport Command. The school began training in 1948 at Fort Nelson, British Columbia, and, two years later, moved to Edmonton, Alberta, with a bush detachment about 200 miles west in the foothills of the Rocky Mountains, and an Arctic detachment, first at Cambridge Bay and now at Resolute.

The object of the school is to instruct members of aircrews and others in the techniques of survival in uninhabited terrain. Subjects taught include first aid, swimming, shelter building, hunting, fishing and fire-lighting, signalling and bush orientation. During the Arctic phase of training students are taught to build igloos and other simple snow shelters, the use of tents in subzero conditions, and methods of fishing through ice. The course lasts for two weeks, except during January to May when it is increased by eight days for Arctic training. Groups of thirty to forty students are received at fortnightly intervals throughout the year, and about 7000 men have been trained since the scheme began. In addition to RCAF aircrews, trainees are received from the Canadian Army and Navy, the United States armed forces and, to a small extent, civilians.

BELGIAN ORGANIZATION FOR ANTARCTIC ACTIVITIES

[Summarized from a note by Mdlle. P. Doyen, Centre National de Recherches Polaire de Belgique.]

The Centre National de Recherches Polaires de Belgique was established at 31 Rue Vautier, Bruxelles, on 8 December 1958 with the following objects:

(*a*) the organization and conduct of polar expeditions, together with the establishment of a cadre of scientific and technical workers;
(*b*) the study of materials, equipment and all matters concerned with polar expeditions;
(*c*) the verification, documentation, publication and study of information and techniques concerning polar expeditions;
(*d*) the collection and preservation of material of polar interest;
(*e*) the continuation of the work of previous Belgian Antarctic expeditions.

Ten working groups have been formed to study the following disciplines in the Antarctic:

(1) aerology, radiation, ozone, atmospheric chemistry and electricity;
(2) geomagnetism, telluric currents, ionosphere, aurora;
(3) cosmic rays and nuclear radiation;
(4) oceanography;
(5) seismology, gravimetry;
(6) geology, geomorphology and glaciology;
(7) geodesy, topography, cartography;
(8) biology, physiology;
(9) computations;
(10) supplies and organization.

Working groups are also responsible for the preparation of scientific programmes under the general guidance of SCAR and the Comité Spécial Belge pour les Recherches dans l'Antarctique. The Centre works in close collaboration with Universities and scientific institutions in Belgium and makes use of the knowledge of outside experts in various subjects.

USE OF JET-PROP AIRCRAFT AT UNITED STATES ANTARCTIC STATIONS, 1960

[Summarized from the *Bulletin of the United States Antarctic Project Office*, Vol. 1, No. 5, 1960.]

Seven C-130 Hercules ski-equipped jet-prop transport aircraft, the first of this type to be used in Antarctica, were used to re-supply the United States "Byrd" and South Pole stations during "Deep Freeze 60", having flown from Christchurch to "NAF McMurdo" in 8 hr. 5 min. They replaced the Globemaster C-124 aircraft from which supplies had been delivered by means of parachute drops during previous seasons.

These 62-ton aircraft are equipped with tricycle ski-wheel landing gear and a lowering and retraction system permitting the use of either skis or low-pressure "doughnut" tyres, and enabling the aircraft to land on unprepared surfaces. The maximum gross weight of the aircraft exerts a bearing pressure of only 5 lb. per sq.in. on the snow. The aircraft are powered by four T-56 Allison engines, developing a total of 15,000 equivalent shaft horse power to drive 15 ft. diam. propellers, and can operate from unprepared airstrips with a 31,000 lb. payload over a 1500 mile range. The cruising speed is 335 m.p.h. The aft doors of the aircraft give access to a cargo compartment 9 ft. high and 10 ft. wide and 41½ ft. long, with the floor of the fuselage only 40 in. above ground level to facilitate loading. The average time taken to unload an aircraft is about 15 min.

The use of these aircraft eliminates the weaknesses of the parachute drop method, ensuring less damage to scientific equipment, less handling of cargo, a maximum delivery of payloads and avoiding expenditure on costly parachutes lost during operations.

The record of the aircraft during the season was: "Byrd" station, 30 flights carrying 160 tons; South Pole station, 28 flights carrying 250 tons.

United States C-130, jet-prop aircraft used for transport in Antarctica during operation "Deep Freeze 60", 1959 60.

Photograph, Lockheed News Bureau

(*Facing p.* 298)

SCAR BULLETIN

No. 6, *September* 1960

Conservation of nature in the Antarctic

Based on a paper read at the Antarctic Symposium at Buenos Aires, 1959.

BY ROBERT CARRICK*

CONTENTS

Introduction

Man's impact on his environment inevitably affects the indigenous plants and animals of the regions he occupies. It is their environment too, and any change in the situations to which all forms of life are nicely adjusted is likely to be detrimental to them. Much of this is unavoidable, due to increasing economic needs, but some of it is both unnecessary and highly undesirable. It is due to wasteful over-harvesting, uncontrolled interference, ill-advised introductions of alien forms, destruction of the resources on which flora and fauna depend, and, in general, to lack of well-informed long-term planning during the earlier stages of human occupation. The Antarctic region, the last to be invaded by man, now presents both a challenge and an opportunity. Serious and permanent impairment of biological values has been confined, so far, to the soils, vegetation, seals and smaller petrels of some sub-Antarctic islands, but the increase in continental stations, and in human activity around Antarctica and its seas, is a threat not to be ignored.

Concern for the welfare of the Antarctic fauna, especially the more unique forms of wildlife which sometimes suffer obvious losses at the hands of man, has been widely expressed by the nations now operating in this area. At the 3rd meeting of SCAR, independent representations on this subject were made by Argentina, Australia, France, the United Kingdom and the United States, and the eleven member nations present unanimously noted the need for conservation of the Antarctic flora and fauna, and recommended that the means of protection be studied.[1] A similar resolution was adopted during the Antarctic Symposium at Buenos Aires,[2] and it is noteworthy that these views are supported as strongly by non-biologists and non-scientists as by those whose opportunities and material for research are affected.

The more evident losses, such as among penguins and seals due to direct human interference, are merely one aspect of the wider and more complex problem of conservation of the Antarctic and sub-Antarctic flora and fauna,

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marine and terrestrial, as a whole. The solution will often be a compromise in the face of legitimate human needs. Its long-term value will depend upon our scientific grasp of the ecological and behavioural relationships within the biotic community, as well as between it and the new and potent intrusion of man and his works. Scientific information, even at survey level, is still inadequate for the drafting of a final and comprehensive plan; but useful interim measures can certainly be prepared now.

The relative importance and urgency for protection varies according to the species involved, the viewpoint adopted, and the nature and imminence of the forces of destruction. It is important to recognize clearly on what grounds the preservation of particular species or associations of Antarctic animals or plants is commended, and how the necessary measures are likely to accord with other aspects of man's life in the Antarctic. All forms of life have scientific value, and if penguins and seals enjoy wider appreciation and are more frequently cited in this paper, their close dependence on marine invertebrates and fish should be borne in mind; the same principles of conservation apply to all.

Aims of conservation

The case for conservation of flora and fauna is threefold: scientific, aesthetic and economic. The weight given to each of these values varies according to the human viewpoint and the species involved, and although these purposes are not always mutually exclusive, when they are it is essential to define priorities clearly in each situation.

Scientific. The scientific claim is always strong, and particularly so in the Antarctic. Study of undisturbed flora and fauna should precede the extension of human activity. Here one of the most rigorous climates in the world has produced living forms which represent the end-point in structural, physiological and ecological adaptation to extremes of low temperature, high wind and day-length. It is the extreme character of biological adaptations in the Antarctic—such as the fitness of warm-blooded penguins and seals for marine life; or the maturation of the gonads of the Emperor Penguin (*Aptenodytes forsteri*) in May, a month before the winter solstice; or the suspended animation of the Elephant Seal Louse (*Lepidophthirus macrorhini*) during prolonged immersion at sea[3]—that offers information of fundamental importance on the extent to which anatomical, physiological, and behavioural mechanisms are perfectable, as well as clear evidence on how they combine to serve ecological ends. The paucity of species in this relatively uniform environment, especially on land, with consequent simplification of interacting systems, offers possibilities for quantitative evaluation of the role of individual species that cannot be found in richer regions. The discontinuous distribution, and the gregarious, overt and regular breeding habits of some penguins, petrels and seals, facilitate census work, sometimes of the entire world population. This enables fluctuations of numbers and distribution to be assessed on a scale and with an accuracy seldom attainable elsewhere. The approachability on land of many birds and seals, the ease with which they can be permanently marked and

observed, and their constancy of location, ensure an unusually rich reward for the student of population ecology and behaviour.

Biogeographical research into problems of the distribution and origins of the flora and fauna of the southern hemisphere, and into related questions of continental drift and the former relations of land masses, is being assisted by evidence from present and fossil plants and animals, especially on sub-Antarctic islands. Many of these oceanic islands, little disturbed by human influence, present biological peculiarities such as floristic and faunistic poverty, a high degree of endemism, and an increased ecological amplitude of the species present, while offering excellent opportunities for the study of insularity. Comparative study of related species through a wide latitudinal range will throw light, for example, on the factors that limit geographical range and control breeding.

The conservation plan should include provision for adequate field study of populations and areas with long-term guarantees from interference. Good conservation measures depend, finally, on sound knowledge of the numbers, distribution, movements, food and other requirements, seasonal cycles and behaviour of the animals and plants concerned. Economic exploitation of fauna and flora should be firmly based on comparative scientific study of natural and commercial populations.

Aesthetic. The aesthetic appeal of most forms of wildlife justifies their conservation, and this is especially true of the Antarctic fauna. Penguins, albatrosses and seals enliven the bleak landscape and open sea, they often occur in spectacular numbers while many are closely approachable and pursue their private purposes regardless of our presence. The intrinsic attractiveness of penguins, enhanced by their upright gait and reciprocal curiosity toward us, places them high indeed on the list of birds that particularly merit our protection.

No less important is the mental and spiritual recuperation derived from contact with living nature, especially to those who are becoming introspective, worried and stressed. Even in ordinary life, where avenues of escape are more plentiful, this often proves an effective one, to which psychiatrists and many people in all walks of life have paid tribute. In the isolation of an Antarctic party, where there are few outside interests capable of filling the mind with pleasant, objective and impersonal thoughts, and of helping to restore perspective, the social value of the local wildlife cannot be overestimated.

Economic. Man's requirements of food and the raw materials obtainable from plants and animals are met partly by harvesting natural populations and, to a lesser extent in the sub-Antarctic, by introducing domesticated or wild food-animals into native pastures. These activities have taken place throughout the sub-Antarctic and Antarctic, with results which have often been regrettable and sometimes disastrous, except from the viewpoint of immediate and temporary profits.

Whaling operations in both Arctic and Antarctic seas are the classic example of over-exploitation of natural, living resources. The free-for-all

methods employed for so many decades, with increasing technical efficiency of weapons and ships, have seriously depleted the numbers of whales. Large-scale commercial operations on terrestrial fauna have centred mainly on the Fur Seal (*Arctocephalus* spp.), and the Elephant Seal (*Mirounga leonina*), with lesser attention to other seals and some penguins. The value of Fur Seal pelts led to the rapid and complete extermination of large populations on many islands, such as Macquarie Island,[4] and serious over-harvesting of Elephant Seals for oil reduced stocks to unprofitable levels.[5] The extensive studies of the Elephant Seal by Laws[6] have done much to put this industry on a less empirical basis. An attempt, in 1959, to resume operations on this species on Macquarie Island was rightly repulsed by Australian public opinion and the Australian Academy of Science; the information on natural population changes emerging from the branding of some 500 pups annually since 1949 is far more valuable to commerce, as well as to science, in the long run.[7] Commercial sealing still continues at South Georgia and Kerguelen, but improved regulations at the former include the issue of licences to limit the kill, the resting of a different quarter of the island each year in rotation, the establishment of four reserves, and the keeping of records of the estimated age of killed bulls.[5, 8] Evaluation of the permissible take of these animals, which will harvest the true surplus without depleting the breeding capital, is a complex ecological and possibly behavioural problem.

On a smaller scale, seals, birds and eggs are used to provide food for men and dogs. The necessity for this is recognized, though it is attended by the same risks as larger enterprises. For example, at Mawson in 1954 at least 93 Weddell Seals, including breeding cows, were taken around the station, and by 1958 the species no longer bred on the local inshore islands and was recorded only farther afield. Similar cases could be cited elsewhere, for, when even small demands exceed the local supply of harvestable surplus and capital is reduced, a vacuum is easily created. The limited dispersal, and constancy of return of many species to the same place, tend to delay recolonization. Eggs and immature stages can usually be taken in large numbers without detriment to the colony or species, because of the heavy natural mortality early in life; but continual disturbance, in a manner to which the breeding adults react adversely, may still cause desertion in favour of more peaceful sites.

Exotic herbivorous animals have been introduced to several sub-Antarctic islands as a useful emergency food measure and in order to create supplies of familiar and more palatable fresh meat and milk. Wild species introduced by sealers and governments include the rabbit (*Oryctolagus cuniculus*) and reindeer (*Rangifer tarandus*); domestic ones are sheep, cattle and goats. The effects of uncontrolled grazing, especially by rabbits, on these highly susceptible pastures and soils are devastating. Predaceous species also introduced, intentionally or otherwise, include cats, dogs, rats and mice. The repercussions of introductions are always imponderable, and the risk is highest to indigenous plants and animals where there are no native herbivores and carnivores, and consequently no defence systems. The communal habit is adequate protection for eggs and chicks against the few native predators. Only those introductions

Rabbit damage to vegetation at Petrel Peak, Macquarie Island. Selective grazing of tussock-grass has led to extensive soil erosion. The dark area A is stable tussock, the light area B is grass killed by rabbits. The area C shows where secondary turf has been unable to hold soil on the slope, and a landslip of soil and peat has occurred from C to D. Eventually rock screes replace the original vegetation, and recovery is impossible.

Photograph by A. B. Costin

(*Facing p.* 302)

Royal Penguins and Elephant Seals at Nuggets Bay, Macquarie Island. These penguins are the non-breeding overflow from the enormous colonies up the valley. Sealers formerly took 10,000 yearlings here annually.

Photograph by R. Carrick

absolutely essential to man's life in the Antarctic region should be permitted; the effects of herbivores on local vegetation should be closely studied and tempered by rotational grazing; and the utmost precautions should be taken to prevent the escape of any type of predator, and to deal with those that do escape.

Problems of conservation

The problems of nature conservation in the Antarctic, and the measures required to achieve success, are no different in principle from those in other parts of the world. Man's occupation and development of this region are still slight, and so, in general, are his effects on the flora and fauna. At present, the scientific and aesthetic importance of Antarctic animals and plants far outweighs their limited commercial value, though this could change and radically alter the situation. This is an opportune moment to take stock of the problems, current and potential, with the scientific approach that is required to see them in perspective, to understand the real causes of each, and to arrive at effective answers.

A much over-simplified picture of biological cycles in the Antarctic community will help as a background to specific problems. All forms of life fit into an intricate interacting system in which the numbers of component species ebb and flow in time as each capitalises upon others to over-produce its kind and cause the compensatory mortality, heaviest in the early stages, which eventually equates death-rate with birth-rate and maintains equilibrium. Food-chain relationships between species tend to be specific, often highly so, and to determine the season and rate of production at the most favourable time of year, as well as to set the level of survival during the least favourable season. The bewildering complexity of inter-specific relationships is somewhat simplified in the Antarctic by the paramount dependence even of most terrestrial fauna on sea-foods. The prolific upsurge of marine life in summer provides abundant quanties of plankton, which sustain the breeding of large numbers of mammals and birds; the terrestrial distribution of these latter is the result, mainly, of scarcity of suitable sites within reach of the appropriate food-supply; and their over-all numbers are annually reduced to the winter level, when less plentiful or less available Antarctic foods cause wide dispersal and even migration out of the region.

The main threat to Antarctic wildlife has yet to materialize; but if, as has been suggested, a food-hungry world were to turn to the Antarctic seas for supplies, and if the lower organisms in the food-chains were to be taken in quantity, this could have profound and permanent effects on higher vertebrates such as whales, seals and birds. This is in accordance with the most important principle of conservation, that preservation of the habitat, especially food, its most vital resource, far outweighs measures to prevent more direct losses, from which all wild populations have a high capacity to recuperate. International agreement will be required to meet this problem, to prevent over-harvesting of wildlife, and to declare as sanctuaries foraging areas around breeding-places. Scientific biological study, oceanographic and terrestrial, is

essential to determine the inter-relations of life forms and the probable effects of man's utilization of them. The quantitative ecological approach has to be complemented by study of other aspects, especially behaviour. Social organisation, for example, may create its own harvestable surplus, as in the polygamous Elephant Seal, but the repercussions of interference with this should be fully understood.

International co-operation and equality of standards are also required to deal effectively with the more direct threats to wildlife on land, which result from commercial exploitation, local utilization and human activities in general. Agreement on permissible harvests and methods, allocation of reference study populations and sanctuary areas from the viewpoint of the Antarctic as a whole, and consistency of aims and measures throughout the region, are essential. The lessons of other parts of the world should be applied; the variety of conservation laws among European countries, with the surprising diversity of approach and legislation are errors to be avoided. The Antarctic is a natural biogeographical entity, and artificial national boundaries have rather less significance for the indigenous inhabitants than for those who make them.

The highly specialized character of the Antarctic flora and fauna, the lack of buffers and defences against unaccustomed interference and attack, the special vulnerability of seals and penguins when out of their natural element the sea, and the tameness and approachability of most Antarctic wildlife, all contribute to a situation that calls for more than ordinary consideration on the part of the human intruder. Accidental damage is easily done and often not realised, as when breeding birds are disturbed by too frequent visitors on foot, by too persistent attention from photographers, or by sight-seeing helicopters close overhead. These cause panic and temporary desertion of eggs or chicks, which fall prey to waiting predators. Losses also occur from thoughtless or careless acts, such as pumping of ships' bilges close inshore, permitting huskies to run free, or negligent driving of vehicles over seals and penguins. We are not always fully alive to the true reaction of wild animals to our presence and interference. Species and individuals vary, and the same individual penguin may stand its ground at the nest-site once brooding has started, but desert its site and mate if disturbed during pair-forming, as banded birds have shown. Penguin colonies show remarkable tenacity for their chosen breeding-place, despite serious disturbance. The New Zealand–United States base at Cape Hallett was situated in an Adélie Penguin (*Pygoscelis adeliae*) colony, through which the airstrip also ran, but the birds persisted in re-invading the strip and endeavouring to nest among the huts. An Antarctic "National Park", or more than one, containing some of the finest scenery and wildlife of this region, situated with a view to tourist access and internationally controlled to conform with the best national park principles, would be an asset of world-wide value for the future.

Scientific study entails collecting specimens as well as handling and marking wildlife. This causes no loss even when sizeable samples are taken, and it will bring permanent gain. Rare vagrants may be collected as proof of identity, for they seldom survive, but remnant and colonizing groups, especially at the

fringe of their range, have greater scientific value alive. The removal of the small colony of King Penguins from Heard Island to Australian zoos is a mistake not to be repeated. The "control" of natural predators is a misguided policy, and "blood sports" as understood in civilized communities have no place in the Antarctic, with the exception of the hunting of rabbits, reindeer, Weka, and possibly a quota of ducks on islands. The local harvesting of eggs, seal meat, etc., for food should conform to the same rules as commercial practices, and should not interfere with animals reserved for pleasure or study.

The introduction of exotic animals to the susceptible Antarctic environment is another aspect of interference with habitat, and the new balance which results from their successful establishment can hardly be other than detrimental to indigenous flora and fauna.

Conclusions

Effective prevention of direct damage and disturbance to flora and fauna depends, ultimately, on the goodwill of all concerned. This can stem only from an appreciation of natural values and a sense of responsibility for community interests. When these are lacking in normal life, it is not easy to inculcate them into party members who undergo a short period of training before spending a year in the Antarctic. It is even more difficult in the case of brief summer visitors, ships' companies, and perhaps one-day tourists. Regulations are necessary, but the attitude of consideration and sense of personal responsibility which will achieve most will derive from knowledge and understanding of the life and behaviour of Antarctic animals, and from an appreciation of them as an unrivalled natural heritage.

Throughout the world, the plants and animals that are products of the land are the property of the owner nations and subject to national laws of wide diversity and efficacy. The living products of the coastal seas, within the territorial limits claimed, enjoy similar legal protection. Those of the oceans are either subject to international agreements (e.g. whales) or free for all. The flora and fauna of sub-Antarctic islands come under the jurisdiction of the parent country, though distance and expense usually combine to make their protection difficult. The Antarctic continent itself is unique in view of the high measure of international co-operation and goodwill in current activities there, and the absence so far of exploitative forces that would seriously threaten wildlife.

An opportunity to take full advantage of this situation now exists. SCAR provides a forum at which scientists can discuss these problems and can recommend the lines of action which will lead to nature conservation in Antarctica. The Antarctic Treaty provides for the first time an opportunity to put into effect a uniform scheme over the whole region south of lat. 60° S., with which it is hoped the conservation policies for the more northerly sub-Antarctic islands would be integrated.

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Scientific stations in Antarctica, 1960

[The following amendments have been notified to the particulars given in 'Scientific stations in Antarctica 1959. *SCAR Bulletin*, No. 2, 1959, p. 15–26, and No. 5, 1960, p. 64–65.]

Argentina

Ellsworth

Personnel: Leader, J. H. Suarez.

Scientists in charge of disciplines: A. Antinucci, physiology; J. C. Luna Perez, biology; W. P. Johnson, meteorology.

Total: 3 scientists, 16 technicians, 8 others.

Decepción

Personnel: Leader, L. Messiga.

Total: 1 scientist, 9 technicians, 4 others.

Melchior

Personnel: Leader, P. Sciumbe.

Esperanza

Personnel: Leader, E. A. Fehrmann.

Total: 1 scientist, 5 technicians, 8 others.

Orcadas

Personnel: Leader, A. Giuntini.

Almirante Brown
Teniente Camara
General San Martín } Not in operation during 1960.

Chile

Capitán Arturo Prat

Climate: Temperature, mean annual −5° C., max. 2·6° C., min. −16° C.

Personnel: Leader, R. Torrens.

General Bernado O'Higgins

Personnel: Leader, E. Bachler.

Presidente Aguirre Cerda
Personnel: Leader, F. Mansilla.

Presidente González Videla
Personnel: Leader, G. Kaempffer.
Climate: Temperature, max. −7·2° C., min. −20·8° C.
Precipitation, estimated annual water equivalent, 103 mm.

France

Dumont d'Urville
Personnel: Leader, A. Faure.
Total: 12.

New Zealand

Scott base
Climate: Temperature, mean annual −20·1° C., max. 5° C., min. −52·7° C.
Wind, mean annual 4·7 m./s., extreme 41·1 m./s.
Cloudiness, mean annual 4·7 oktas.
Facilities available: Buildings 14, accommodating 22.
Electrical power, 96 kW.
Aircraft: 1 Auster.
Personnel: Leader, J. Lennox-King.
Total: 5 technicians, 9 others.

United Kingdom

Port Lockroy (Base A)
Personnel: Leader, P. H. Leek.
Total: 5.

Hope Bay (Base D)
Personnel: Leader, C. G. Brading (survey).
Scientists in charge of disciplines: A. Allan, geophysics; J. Hampton, physiology; P. H. H. Nelson, geology; G. J. Pearce, meteorology.
Total: 15.

Argentine Islands (Base F)
Facilities available: 6 buildings, accommodating 18.
Electrical power: 15 kW.
Personnel: Leader, C. Murray.
Scientists in charge of disciplines: H. E. Aggar, geophysics; A. Miller, meteorology; B. R. Sparke, physiology.
Total: 12.

Admiralty Bay (Base G)
Personnel: Leader, C. Barton (geology).
Scientists in charge of disciplines: J. E. Ferrar, meteorology and glaciology; N. V. Jones, zoology.
Scientific programme: Geology and zoology added.

Signy Island (Base H)
Personnel: Leader, R. B. Harrison.

Horseshoe Island (Base Y)
Personnel: Leader, P. Forster.
Scientific programme: Geology, survey, physiology.

Halley Bay (Base Z)

Personnel: Leader, N. Hedderly (meteorology).

Scientists in charge of disciplines: D. A. Ardus, glaciology; C. Forrest, physiology; A. G. Lewis, ionospherics; M. Thurston, biology.

Total: 16.

Scientific programme: Ionospherics added.

South Georgia

Location: lat. 54° 16′ S., long. 36° 30′ W.

Site: on rock. Method of supply: by sea.

Climate: Temperature, mean annual 1·5° C., max. 24° C., min. −14° C.

Cloudiness, mean annual 5·6 oktas.

Precipitation, estimated annual water equivalent, 1596 mm.

Facilities available: 2 buildings, accommodating 5.

Electrical power, 175 kW.

Tractors, etc.: Massey Ferguson 35, diesel.

Personnel:

Scientists in charge of disciplines: W. N. Bonner, biology; D. Borland, meteorology.

Total: 5 scientists.

Scientific programme: Biology, meteorology—surface observations, magnetism, gravity, hydrographic survey.

Exchange of foreign observers in the Antarctic, 1959–60

Name	Country of origin	Occupation	Host country
A. C. Bogdanovich	United States	Physician	Chile
R. Dartevelle	Belgium	Meteorologist	United States
G. Dewart	United States	Glaciologist	U.S.S.R.
*L. D. Drury	United States	Meteorologist	Argentina
P. Fierro H.	Chile	Naval Officer	United States
*P. R. Fundenburg	United States	Meteorologist	Argentina
D. A. Lewis	United States	Foreign Service Officer	Australia
C. Lorius	France	Glaciologist	United States
G. McKinnon	Australia	Geographer	United States
S. Mandarich	United States	Naval Officer	Norway
*G. Mikk	United States	Meteorologist	Argentina
R. G. Miller	United States	Marine Biologist	Argentina
J. E. Rawson	Argentina	Naval Officer	United States
J. E. Sater	United States	Photogrammetrist	United Kingdom
D. Shoji	Japan	Oceanographer	United States
C. L. Trainer	United States	Meteorologist	New Zealand ("Hallett")
*W. H. Whitson	United States	Auroral Physicist	Argentina
K. A. C. Wirdman	United Kingdom	RAF Officer	United States
S. Yevteyev	USSR	Glaciologist	United States

* These observers were assigned to "Ellsworth" station, but were unable to reach their posts owing to the state of the ice in the Weddell Sea. They accompanied the Argentine supply expedition during December 1959 and January 1960.

OBITUARY

THOMAS COUZENS, Royal New Zealand Army Corps, died in the Ross Dependency, Antarctica, on 19 November 1959, as the result of an accident. He was driving one of the two Sno-cats taking part in the New Zealand Geological and Survey Expedition to Victoria Land when his vehicle plunged into a hidden crevasse and he was killed. Two others with him, B. M. Gunn and J. H. Lowery, were severely injured, but were later rescued. Lieutenant Couzens, who had had considerable experience in driving tracked vehicles in snow and ice conditions in Korea, was also a mountaineer and a civilian parachutist.

FATHER THOMAS CUNNINGHAM died at Point Barrow, Alaska, on 3 September 1959 at the age of 53, after 25 years missionary service in various parts of Alaska. In addition to his intimate knowledge of the Eskimo people he was a noted authority on sea ice.

BRIGADIER GENERAL PAUL V. KANE, died on 1 July 1959 at the age of 66. In the course of a distinguished military career, which included service in North Africa and in Germany during World War II, he commanded Task Force "Frigid", 1947, which conducted cold weather tests of men and equipment in Alaska and the Aleutian Islands.

ERRATA

The *Polar Record*, Vol. 10, No. 64, 1960.

Page 4, line 4 of key to map. *For* $\frac{1}{3}$ *read* $\frac{3}{4}$.
Page 5, line 29. *For* 400 *read* 4000.
Page 61, line 2. *For* 128° 3′ *read* 131° 43′.
Page 80, line 17. *For* 50 mm. *read* 50 m.
Page 112, line 38. For *United States Naval Institute Proceedings* read *National Geographic Magazine.*

The *Polar Record*, Vol. 10, No. 65, 1960.

Page 167, line 31. *For* "Melchoir" *read* "Melchior".
Page 175, line 43. *For* Vice- *read* Rear-.
Page 179, line 8. *For* Nouville-Amsterdam *read* Nouvelle-Amsterdam.

RECENT POLAR LITERATURE

This selected bibliography has been prepared by R. J. Adie, Terence Armstrong, T. H. Ellison, Amorey Gethin, J. W. Glen, W. B. Harland, H. G. R. King, Brian Roberts and Ann Savours. Its main field is the polar regions, but it also includes other related subjects such as "applied" glaciology (e.g. snow ploughs and ice engineering). For the literature on the scientific study of snow and ice and of their effects on the earth, readers should consult the bibliographies in each issue of the *Journal of Glaciology*. For Russian material, the system of transliteration used is that agreed by the U.S. Board on Geographic Names and the Permanent Committee on Geographical Names for British Official Use in 1947 (see *Polar Record*, Vol. 6, No. 44, 1952, p. 546).

Reprints of "Recent Polar Literature", from Nos. 37/38 onwards, can be obtained separately (to allow references to be cut out for pasting on index cards) from the Institute, price 2*s*. 6*d*. for two prints. Copies will be sent without charge to organizations with which the Institute maintains exchange arrangements and which notify their wish to receive them. Readers can greatly assist by sending copies of their publications to the library of the Institute.

To increase the usefulness of the bibliography entries have been arranged provisionally under subject headings in classified order according to the Universal Decimal Classification.

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